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CONTROL OF INDUSTRIAL WASTES IN MUNICIPALITIES

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Ministry
of the
Environment

The Honourable
William G. Newman,
Minister

Everett Biggs,
Deputy Minister

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CONTROL OF INDUSTRIAL WASTES
IN MUNICIPALITIES

COURSE MANUAL

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CONTROL OF INDUSTRIAL WASTES
IN MUNICIPALITIES

A CERTIFICATE COURSE MANUAL
PREPARED BY THE
INDUSTRIAL WASTES BRANCH - 1972

REVISED 1973
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Training, Certification & Safety Section
Ministry of the Environment
40 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

INTRODUCTION

The Control of Industrial Wastes course covers five days at the Ministry of the Environment training facilities. The course consists of lecture-discussions on the control of liquid industrial wastes in municipalities.

The principal objective of the course is to introduce the student to the fundamentals of:

- Sewage plant operation
- Industrial processes which generate liquid wastes
- Conducting of liquid industrial wastes surveys.

This is a practical course in which each person will be expected to take an active part in subject discussions and to acquire as much practical knowledge as possible from the lectures and from the demonstrations presented during the course.

R. R. Doddridge, Manager
Training, Certification & Safety
Technical Services Branch

January, 1975

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CHAPTER 1

SEWAGE TREATMENT PLANT

PRIMARY TREATMENT

Primary treatment is the initial mechanical stage of a treatment plant process. Basically, it removes suspended solid materials from the water. It includes coarse screening, to remove large material, grit settling, to remove heavy inorganic matter, and comminution (shredding), to break down the remaining suspended solids. The sewage passes to a primary clarifier for further settling of the remaining material. The clarified liquid continues on in the process for additional treatment or, if the plant provides only primary treatment, the liquid is disinfected by chlorination and discharged to the receiving watercourse. Figure 1-1 "Primary Sewage Treatment" shows schematically the sequence of the process. The settled material, or sludge, accumulated in the primary is usually pumped from the clarifier to a tank known as a digester where it is broken down into more stable elements.

The digestion of sludge is not strictly essential to the sewage treatment processes, but it does provide further desirable treatment. Digestion reduces the volume of sludge to be disposed of. It renders the solids hygienically more acceptable. In fact, digestion may be considered as "secondary treatment" for the solid portion of the sewage. The raw sludge is fed to a digester where microorganisms partially degrade the material. The most common type of digestion process has been anaerobic (without oxygen) although aerobic (with oxygen) digestion is becoming more common.

The anaerobic digestion process consists of a closed tank with microorganisms feeding on the organic material. Gas, mostly methane, is produced and may be used as a fuel for the sewage plant boilers. The sludge produced is drawn off for disposal. The supernatant liquor in the digester may be drawn off and returned to the settling section of the plant.

In aerobic digestion, the sludge is mixed and air is passed through it. The microorganisms in this case require free oxygen to enable them to feed upon the organic material.

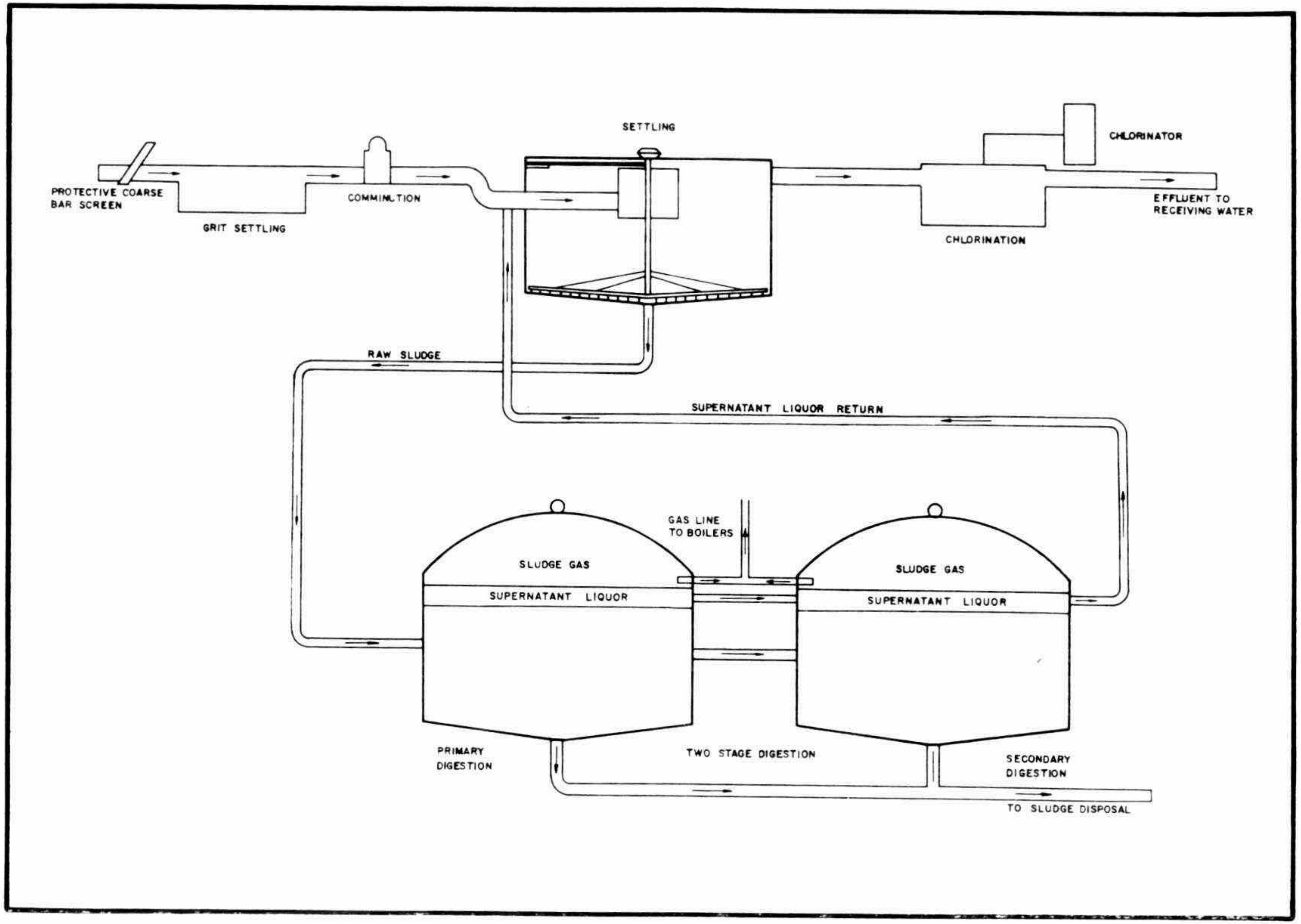


Figure 1-1
Primary Sewage Treatment

The sludge produced is similar to that of anaerobic digestion.

Following digestion, some form of dewatering is normally carried out before final disposal. Methods used may include centrifuging, elutriation, vacuum filtration or air drying. Land dumping is a common method of disposal. Incineration is also practised.

SECONDARY TREATMENT

When provided, secondary treatment will follow primary treatment. Here, the waste is "broken down" into simpler substances by microorganisms present in this stage of the process. One of the most commonly used secondary treatment systems is the activated sludge process. The conventional activated sludge process consists of an aeration tank and a secondary clarifier. The waste from primary treatment enters the aeration section where air is bubbled through it by means of surface aerators or air diffusers. The oxygen supplied is used by the microorganisms which degrade the organic matter in the sewage. Since they require free oxygen, the microorganisms are known as aerobes. Microorganisms use the organic portion of the waste as food. The effluent from the aeration section passes to the secondary clarifier (final settling) where the biological material is allowed to settle out. The effluent is disinfected by chlorination before being discharged to the receiving watercourse.

The solid material which collects in the settling section is known as activated sludge. It is composed of living biological material. A portion of the sludge is recirculated to the aeration tank to treat other incoming raw sewage. Because the microorganisms are constantly growing and multiplying, the remaining portion of the sludge must be discarded to maintain a healthy and constant ratio of food (F) to microorganisms (M) commonly referred to as the F/M ratio. The discarded activated sludge is usually fed to the settling section of the primary treatment and proceeds to the digester and final disposal. Figure 1-2, "Secondary Sewage Treatment (Activated Sludge)" shows schematically the primary and secondary stages.

There are other types of secondary treatment including contact stabilization, aerated lagoon, trickling filter, oxidation ditch, etc. These differ from the conventional

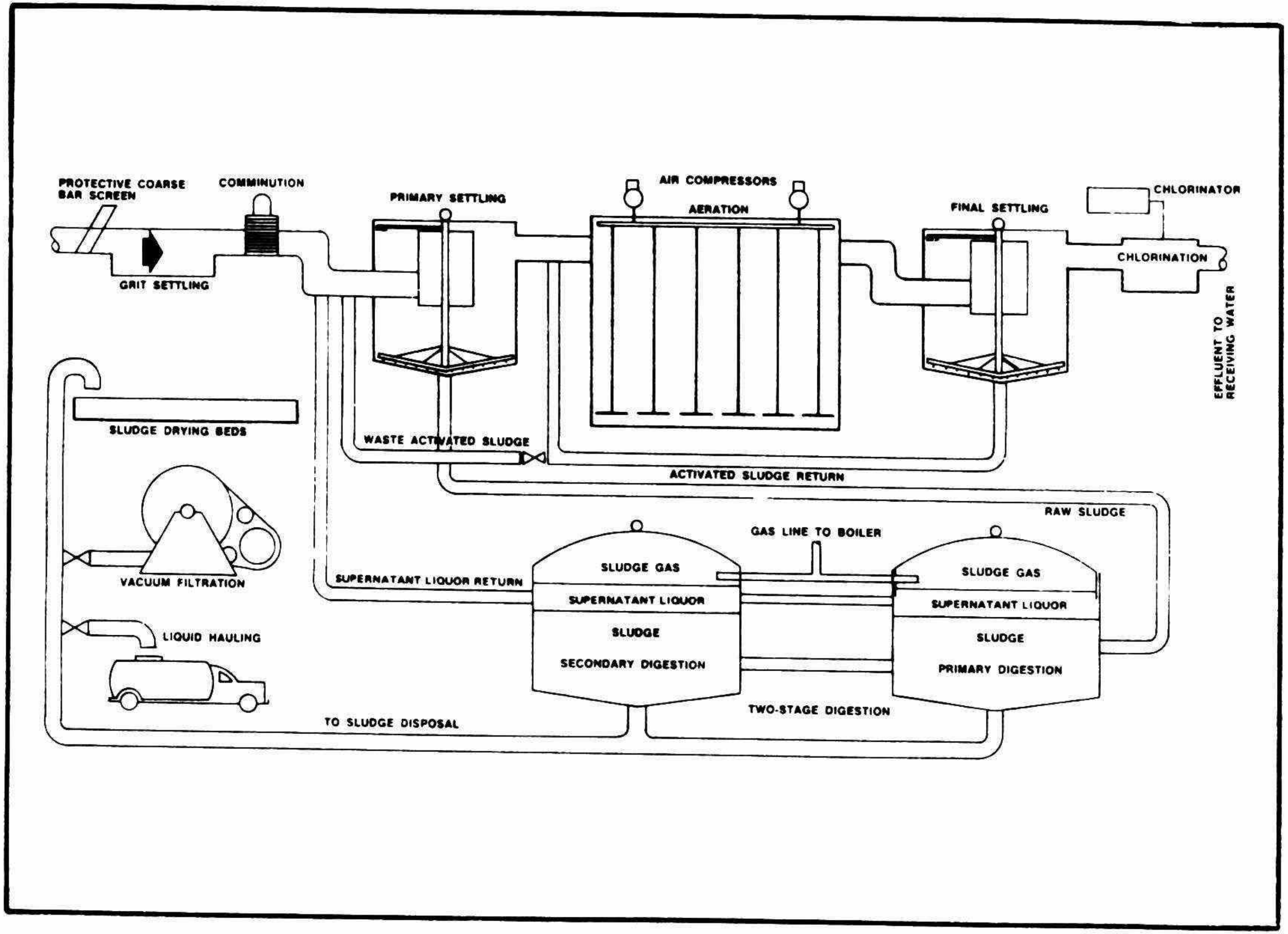


Figure 1-2
Secondary Sewage Treatment Activated Sludge

activated sludge system only in the method by which treatment is effected. The basic process whereby the waste is used as food by microbes remains the same.

TERTIARY TREATMENT

Tertiary treatment cannot be described in the same straightforward terms as the primary and secondary treatment. Many different processes are available but none as yet has become the conventional practice. Tertiary treatment includes physical/chemical processes such as chemical interaction and precipitation, reverse osmosis, carbon adsorption, filtration, etc. The objectives of the primary and secondary stages of the process are to remove solids and organic material and to disinfect the sewage. The objectives of tertiary treatment include removal of very fine solid matter and removal of materials such as phosphorus, nitrogen, taste and odour causing components, dissolved solids, etc.

SUMMARY

1. Primary treatment removes some of the solids and some of the organic materials.

2. Secondary treatment removes most of the remaining solids and most of the remaining organic material.

3. Tertiary treatment removes any remaining contaminants to ensure an acceptable effluent.

4. Disinfection of the effluent prior to final discharge is routine and chlorine gas is normally used for this purpose.

CHAPTER II

GENERAL CHARACTERISTICS AND PROBLEMS OF INDUSTRIAL WASTES

INTRODUCTION

Contaminants in a waste may be divided into two general groups:

(1) contaminants in suspension; and
(2) contaminants in solution.

Treatment plants normally remove suspended materials first and then handle the dissolved components. The characteristics of industrial wastes will be divided into categories such as solids, metals, cyanides, greases, oils, and colour.

SOLIDS

Solids in a waste can be subdivided into suspended solids and dissolved solids. Suspended solids consist of particulate matter entrained in the waste and varying in size from small particles, such as measured in the micron range, to larger particles, such as wood fibre from the pulp and paper·industry, fruit and vegetable particles from the canning industry, and salt and sand from gravel washing operations. Dissolved solids consist of all materials held in solution.

Laboratory tests are used to determine the amount of solids contained in any wastes. A portion of the waste (aliquot) is taken, using a sample bottle. Following standard procedures, the waste sample is filtered under controlled conditions. The particulate matter caught and left on the filter paper is the suspended solid. The liquid which passed through the filter paper is evaporated. The material remaining in the crucible after evaporation is the dissolved solid. The sum of the suspended solids and dissolved solids is the total solids contained in the waste. All concentrations are recorded in milligrams per litre (mg/l) or parts per million (ppm).

Suspended Solids

Suspended solids can be divided into settleable solids and non-settleable solids. Little difference will be made here, since the effects of settleable and non-settleable solids are almost the same. Settleable solids and the rate of settling are important when designing treatment systems that remove solids by sedimentation. The size of the treatment facilities depends on the settling rates of the entrained matter. The amount of settleability depends upon quiescence, temperature, density and other factors.

Effects of Excessive Suspended Solids on Watercourses

Wastes containing excessive amounts of suspended solids discharged to the watercourse can kill fish by simple abrasive action and by clogging gills and other vital respiratory passages. Suspended solids can destroy benthal organisms and roe, and can ruin spawning beds if they blanket a stream or lake bottom. A heavy discharge of suspended solids can cause turbidity, preventing the passage of sunlight necessary for healthy growth of vegetation in the watercourse. Suspended solids removal from a waste discharge is therefore essential.

Effects of Suspended Solids on Sewage Treatment Plants

Suspended solids can cause serious problems at sewage treatment plants. Abrasive materials can wear out sewers, piping, and pumps, causing extensive maintenance problems. A heavy suspended material that can settle out readily and harden on the bottom of the clarifiers can damage the rake mechanism. Excessive solids in the primary treatment increase the solids handling problems in plant operations.

An excessive amount of readily biodegradable suspended solids could be introduced to a secondary treatment system. Enmeshed with biological floc, it could settle out prematurely in the most quiescent corners of the aeration chamber and begin to turn septic.

A secondary treatment system requires the return of some sludge from the clarifier to the aeration facilities. If this sludge contains a high percentage of inert suspended solids, insufficient active sludge may be recycled. The operation of the secondary stage could be upset. Sludge recycle rates have to be manipulated for an effective treatment plant.

Dissolved Solids

Dissolved solids normally include such waste components as carbonates, bicarbonates, chlorides, sulphates, calcium, magnesium, sodium, and potassium. Generally, these materials are not serious pollutants; however, if their total concentration is high, some problems may result. Dissolved solids can also include dissolved metals and toxic organic compounds. These materials are discussed individually elsewhere because they show specific adverse effects at low concentrations.

Effects of Dissolved Solids on a Watercourse

Dissolved solids can create problems in a watercourse if discharged in excessive concentrations. Some solids can impart a taste or odour to the water and render it unfit for human consumption. High dissolved solids concentrations can alter osmotic pressure and create stresses in microscopic aquatic mechanisms resulting, for instance, in ruptured cell membranes.

Effects of Dissolved Solids on Sewage Treatment Plants

Dissolved solids, except in extreme cases, have little or no effect on proper sewage treatment plant operation. High chloride concentrations, for example, have been discharged to a sewage treatment plant without any apparent adverse effects. If the flow of high concentrations of dissolved solids fluctuates greatly, the result is a shock load effect that could upset the process. These occurrences are usually infrequent.

BIOCHEMICAL OXYGEN DEMAND (BOD)

Biochemical oxygen demand, denoted by the term BOD, represents the quantity of material that will oxidize under biological influences. The BOD concentration does not reveal the concentration of a specific substance, but measures the effect of a combination of substance and conditions.

An oxygen demand in a waste can be exerted by:

- Carbonaceous organic material used as a source of food by aerobic organisms.
- Oxidizable nitrogen derived from nitrate, ammonia, and organic nitrogen compounds which can serve as food for bacteria.
- Certain chemical reducing compounds which normally are associated with industrial waste discharges.

Eventually, these compounds will be oxidized by bacteria, at which time the dissolved oxygen in the water is used up. The amount of oxygen consumed is a measure of the BOD. The longer the material remains in the water, the more oxygen it will consume. The length of time used to measure BOD is normally set at 5 days, hence the more exact term is 5-day BOD (BOD_5).

In the laboratory, BOD is determined by taking a sample of waste. The sample is diluted by adding distilled water saturated with oxygen. The water has been earlier seeded with bacteria (normally from an activated sludge plant). Two dilution sample sets are prepared: one is incubated at 20°C for 5 days, the other set is analyzed immediately for dissolved oxygen. After 5 days, the incubated samples are analyzed for dissolved oxygen. The difference in the oxygen content indicates the biological oxygen demand of the waste.

If there is a toxic constituent in the waste, the biological activity may be reduced during the incubation period, indicating a low BOD concentration. Some wastes require a longer incubation period than the usual 5-day period. The nature of the waste must therefore be known to some extent before the BOD figure can be used effectively.

5-day BOD in itself is not very meaningful, since BOD is not a pollutant and causes no direct harm. BOD is meaningful if the dissolved oxygen content in the watercourse is reduced below levels that can sustain biological life. If natural re-aeration of streams exceeds oxygen consumption rates due to BOD, the pollution effects are minimal.

High BOD demands are significant. They can cause septicity. They can decrease oxygen levels to the point where the water cannot sustain a biological community. In lakes or slow moving streams, septic conditions can lead to turbidity, odour problems, and unsightly conditions. The discharge of BOD material to a watercourse must therefore be controlled.

The BOD parameter is essential in sewage plant design and operation. One of the main objects of the sewage treatment plant is to stabilize the waste. This, in effect, means removing all, or most, of the materials exerting a BOD. The amount of BOD requiring stabilization dictates the size of the aeration basin, sets out the amount of oxygen that must be supplied to the waste, limits feed rate, establishes sludge recycle rates, etc. By doing BOD analyses at the various process stages at the sewage treatment plant, the operator can evaluate the operation of his plant.

If high quantities of materials are discharged to a sewer exerting a high BOD, they can overtax existing aeration facilities at a sewage treatment plant. Insufficient oxygen levels in the plant will lead to insufficient dissolved oxygen levels in the overflow to the secondary clarifier. The higher BOD loading may affect sludge characteristics and produce a poor settleable sludge. Only partial treatment of wastes will occur and a poor quality effluent is released to the watercourse.

CHEMICAL OXYGEN DEMAND (COD)

The BOD test cannot be used for on-the-spot checks, since it takes 5 days to carry out. The chemical oxygen demand (COD) represents the amount of oxygen required to stabilize a waste chemically. Similar to BOD, the COD measures the effects of a combination of materials and does not reveal the concentration of a specific substance.

In the laboratory, COD is determined by taking an aliquot of the waste and boiling it in known amounts of chromic and sulphuric acid. Excess chromate is titrated and the COD value is related to the amount of dichromate consumed.

BOD and COD relationships in a waste should be determined before conducting lab tests. This makes it possible to perform COD analyses, estimate BOD concentrations, and check on the operation of the treatment system. COD tests may exclude some organic compounds in the waste which could exert a BOD (e.g., acetic acid).

METALS

Metals are found in different forms in wastes. They may be found in solution as ions, or in suspension as insoluble hydroxides or insoluble salts. Metals may be present therefore as suspended or dissolved solids. It is best to discuss them separately on an individual basis, however, because they are normally very toxic. Special treatment systems have to be designed to remove them from the waste.

Metals are normally introduced to a watercourse as a result of an industrial waste discharge. In some cases, natural leaching of a metal into a watercourse may occur if there are ore bodies exposed to natural elements such as rain, frost, erosion, etc. As a general rule, metals are present in a sanitary sewer as a result of an industrial waste discharge.

Metals may be extremely toxic both to biological life in a watercourse and to bacterial sludge necessary in sewage treatment plant operation. Because of their toxicity, metals have been responsible for numerous fish kills in the Province. Metals also exhibit synergistic effects; that is, one metal can increase the toxicity of another so that their combined concentration is more lethal than if either metal were found in a watercourse by itself.

Metals can also disrupt the proper operation of a sewage treatment plant. In extreme cases, bacteria in a biological system may be killed entirely. At lower concentration levels, metals may be picked up by bacterial sludge and may accumulate in the digester to toxic levels at which the digester could no longer function.

Some of the more common metals found in wastes are listed in Table A.

ORGANIC COMPOUNDS

A number of organic compounds in solution require special attention because they exhibit their own peculiar traits.

TABLE A

SOME COMMON METALS FOUND IN INDUSTRIAL WASTES

METAL	EFFECT ON WATERCOURSE	EFFECT ON SEWAGE TREATMENT PLANT	COMMENTS
Chromium	Toxic to fish in concentrations from 5 ppm to 10 ppm	Toxic to biological sludge in concentrations in excess of 10 ppm	Found in hexavalent and trivalent state
Copper	Toxic range to fish is 0.1 ppm to 1 ppm	Toxic to biological sludge	Exhibits synergistic effects with zinc
Iron	Toxic range to fish is 0.2 ppm to 2 ppm	Less toxic to biological sludge	Easily forms hydroxide and settles out in primary treatment works
Lead	Toxic range to fish is 0.1 ppm to 5 ppm	Toxic to bacterial sludge	Metal can accumulate in fish tissue
Nickel	Toxic to fish	May be toxic to bacteria at 2 ppm	Forms complex with cyanide
Zinc	Toxic range to fish is 0.1 ppm to 1.0 ppm	Toxic to bacterial sludge	Exhibits synergistic effects with copper

Some are very toxic, such as phenol and cyanide. Oils and greases can also be harmful.

PHENOL

Phenol is a colourless crystalline substance with a characteristic medicinal odour. It is used as a disinfectant and in the manufacture of various plastic resins. It is very soluble in water. As a result, it can become a serious contaminant.

Phenol in domestic waters can cause a serious nuisance problem. During the chlorination of drinking water, phenols also become chlorinated. Even at extremely low concentrations (0.002 mg/l) phenols produce an objectionable taste. This taste has upset many operations at breweries, distilleries, and soft drink bottling plants.

Phenols in a watercourse are toxic. They can cause extensive fish kills even at concentrations in the 0.1 mg/l range. At lower concentrations, they are toxic to lower biological forms, thus destroying the delicate balance of an aquatic environment.

Phenols at high concentrations can cause a shock load and be toxic to bacteria used in activated sludge treatment plants. After being properly acclimatized, a secondary sewage treatment plant can be used to treat phenolic discharges. The feed rate to the plant should be maintained at near constant levels to eliminate shock load and withdrawal effects. Biological systems have successfully treated industrial wastes containing high phenol concentration.

CYANIDE

Cyanide is introduced to the waste in various forms. All of these forms liberate the toxic hydrogen cyanide gas, characterized by an almond smell, whenever the pH of the effluent drops below a value of 8. Cyanide is used extensively in plating industries. It is normally associated with other metals such as copper, zinc, and cadmium. Cyanides may also be discharged from gas works, coke ovens, and chemical industries.

Cyanide is extremely toxic to fish and has been responsible for numerous fish kills. Cyanide can increase the toxicity of metals and hence render normal background levels of metals lethal to aquatic life.

The discharge of a strong cyanide waste to a sanitary sewer is a potential health hazard. Cyanide gas can be liberated from the waste; it can become trapped in poorly vented manholes and other dead areas in the sewers and become a real hazard to sewer maintenance workers. Cyanide is extremely toxic to bacteria. It can create operational problems at the sewage treatment plant. Enough cyanide in the waste can kill off the bacteria in the secondary stage, necessitating a new start up of operation. The introduction of small amounts of cyanide into a treatment plant at constant levels may allow the bacteria to become acclimatized and treat the waste quite effectively.

OILS AND GREASES

Oils and greases in wastes are commonly denoted by the term ether solubles or hexane solubles. The term does not differentiate between materials of animal or mineral origin. Since oils and greases act very similarly, they can be readily discussed and denoted by the same term. Oils and greases having an animal or vegetable origin are somewhat less noxious since they are more biodegradable.

Large quantities of oil discharged into a watercourse can create extensive damage. Beaches covered with oil become unsightly and cannot be used for recreational purposes. Water fowl, weeds, and other vegetation covered with oil cannot continue their normal life functions and die. Small quantities of oil can spread and cover large surface areas of water. This prevents the proper penetration of light so necessary for proper weed growth. In domestic water supplies, oils can impart unpleasant taste and odours rendering the water unfit for human consumption. Treatment is necessary to prevent the discharge of these materials to a watercourse.

Large quantities of grease and oil can create problems in a sewage plant. Grease can combine with other solids and produce large round solid masses more commonly known as "grease balls". A sufficient number of these can plug sewers and lines creating maintenance problems. Smaller grease balls floating on the surface of clarifiers and aerators create an unsightly mess. Their removal becomes an extra procedure in plant operation.

Oils also form unsightly scums on surfaces of clarifiers and aerators. Oil can cover equipment, plug diffuser air nozzles and create other maintenance problems. In sewage treatment lagoons, oil can cover the surface of the pond and interfere with the oxygen transferring mechanisms. Extensive quantities of oil become a fire hazard, especially if the oil contains gasoline that can evaporate and form an explosive mixture with air.

Steps should be taken at the source to prevent excessive oil discharges to the sanitary sewer.

NUTRIENTS

The term nutrient normally refers to nitrogen and phosphorus compounds in the waste that promote the growth of weeds and algae. An overabundant growth of weeds and algae creates nuisance problems in recreational areas. Masses of algae rotting on shore create odour problems, destroy the value of water-front property and make the area uninhabitable. Treatment systems have now been designed to remove these materials from the waste.

COLOUR AND TURBIDITY

Colour and turbidity are useful conditions when determining the nuisance values of some wastes. Strongly coloured effluent, for example, from a dyeing industry, may impart an objectionable colour to a lake or river and destroy its aesthetic value. Highly turbid streams can prevent a proper passage of light necessary for good aquatic growth. In some cases, dyes can be broken down quite readily in a sewage treatment plant. In most cases, however, the more modern dyes are extremely stable and can only be handled by dilution.

Determining Toxic Levels

In some cases, it is difficult to assess the nature of a particular waste and predict its harmful effects on aquatic life. A toxicity test is carried out to determine whether such a waste can be released to a watercourse. This test involves immersing minnows into various dilutions of the waste and studying the effects on the fish. If the fish survive, the effluent is considered non-toxic. If the fish die, the dilution is noted and used to set an effluent quality standard. With more and more new chemicals being created, the toxicity test has become a handy tool to evaluate some of the more exotic types of wastes.

CHAPTER III

GENERAL METHODS OF TREATMENT OF INDUSTRIAL WASTES

INTRODUCTION

Industrial waste effluents are physical mixtures or solutions of solid, liquid or gaseous components in water. How best may the concentration of the offending component be minimized or eliminated from the water? To answer this question, three basic systems will be dealt with:

(1) Water-Solid Systems,
(2) Water-Liquid Systems,
(3) Water-Gaseous Systems.

Most of the problems encountered in the industrial wastes field are with water-solid systems. Other types of systems do exist, however, and can create severe pollution problems.

WATER-SOLID SYSTEMS

A water-solid system may involve two categories:

(a) Suspended Solids
(b) Dissolved Solids

Dissolved solids systems may be broken down into two subcategories, "dissolved organic solids" and "dissolved inorganic solids". Such a breakdown, however, could lead to some confusion as a number of the treatment systems to be discussed are applicable to both organic and inorganic solids. Therefore, "Dissolved Solids" will be dealt with on the basis of treatment systems and mention will be made if a particular system is applicable to the treatment of both dissolved organic and dissolved inorganic solids.

Suspended Solids

Standard techniques that are applied universally to the problems of water-suspended solids separation include screening, settling and filtering.

Screening

Screening is the use of any device containing holes which allows the liquid to pass but not the solids. Screening is the simplest method of separating suspended solids from liquids.

In practical industrial applications, a variety of shapes and sizes of screens are found. Screening generally represents the cheapest method to effect a solids-liquid separation. Screens have one major drawback: the holes get plugged by the solids resulting in a subsequent reduction of liquid throughput. Innovations in screen design have attempted to overcome this drawback. One innovation imparts some mechanical action to the screen to make it self-cleaning. A more recent innovation, the DSM screen (Dutch State Mines), directs a jet of the liquid-solids suspension tangentially onto the surface of a vertical parabolic screen. The solids are retained on the surface of the screen and fall downward under the action of gravity while the water passes through the screen.

The finer the screen (i.e. the smaller the holes), the greater the screen area required for a given liquid throughput. This places a practical limit on the size of solid particles that can be removed by screens. In general, the use of screens is restricted to the removal of larger size particles, seldom less than 150 microns (0.006 inches or 100 mesh).

Some of the more common types of screen include (a) Gravity Sidehill, (b) Rotary Screen and (c) Vibrating Screen.

(a) Gravity Sidehill

Gravity Sidehill is simply a vertical piece of wire mesh or a number of equally spaced metal bars (see Figure 3-1). The liquid-solids mixture is poured onto the surface of the screen or bars. The liquid passes through while the solids are retained by the screen, fall by gravity and are collected at the bottom.

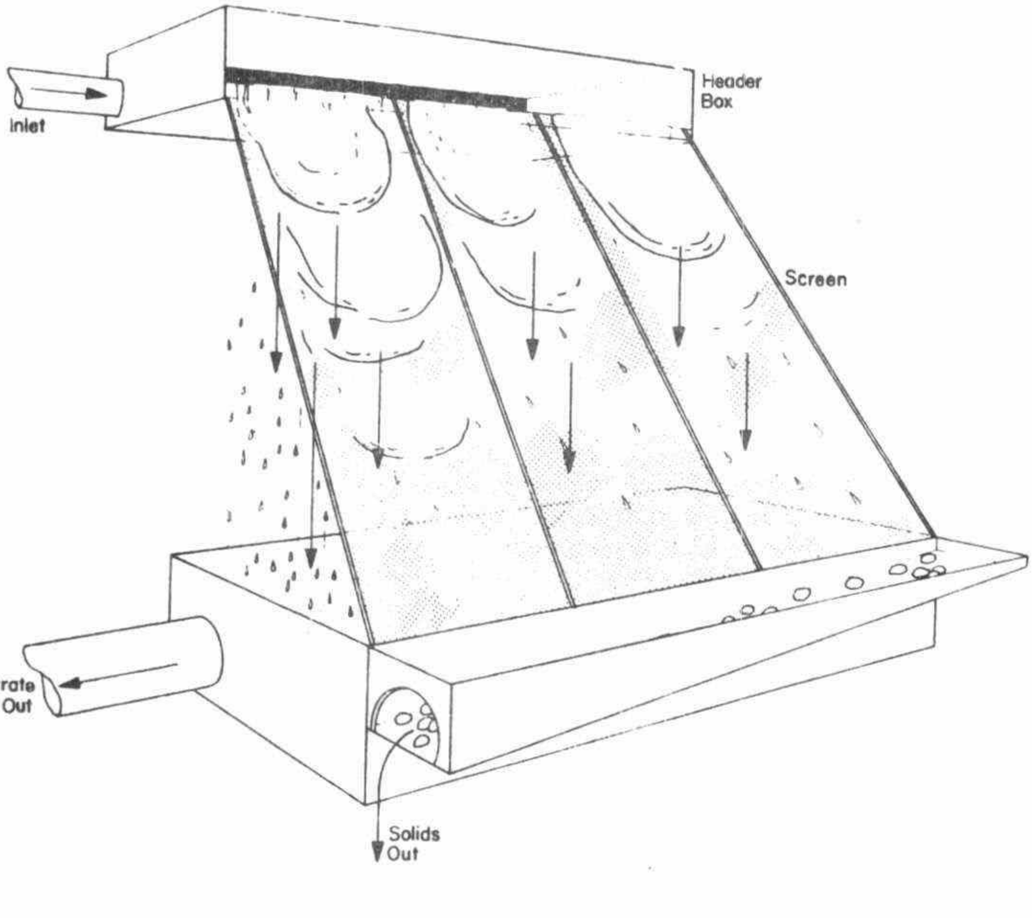


Figure 3-1
Sidehill Screen

(b) Rotary Screen

The rotary screen consists of a wire mesh formed either into a cylinder which is rotated or an endless belt. The liquid-solids mixture is fed to the inside of the cylinder, allowing the water to pass through the mesh and the solids to accumulate inside the cylinder. The mixture can also be fed to the outside of the cylinder allowing the liquid to flow through the mesh to the inside of the cylinder while the solids accumulate on the outside surface. Suitable devices are arranged to remove the accumulated solids.

(c) Vibrating Screens

Vibrating Screens may be rectangular or circular in shape, inclined, have more than one unit of mesh stacked one above the other. A vibrating motion is imparted to the screen to keep it from plugging. This vibrating motion is also imparted to the accumulated solids so that they flow to a suitable discharge point.

Sedimentation

Sedimentation utilizes the fact that suspended solids particles having densities greater than that of the water in which they are suspended move through the water under the influence of a suitably applied force. In most sedimentation systems the applied force is gravity and the movement of the solids through the water is termed settling. Another system, the centrifuge, uses the centrifugal force as the applied force. The movement of the solids is outward from the axis of rotation of the centrifuge.

The type of sedimentation device to be selected will depend, to some extent, on the amounts of settleable solids present in the mixture. If large quantities of solids are present, select a system in which the removed solids can be easily recovered for continuous disposal. If the quantity of solids is relatively small, select a system wherein the accumulated solids are only recovered for disposal once or twice per year. Another system available does not recover the solids; the system in effect is a disposal system - e.g. mining industry tailings areas.

It is not always possible to settle-out all of the suspended solids within a practical time interval. Bench and pilot studies will normally determine the fraction of the suspended solids that can be removed by settling. The following are examples of different sedimentation techniques:

(a) Sedimentation or Settling Ponds

Sedimentation ponds may range from suitably shaped holes dug in the ground to concrete basins. They provide a quiescent environment in which the solid particles can settle and sufficient capacity for the settled solids to accumulate without interfering with the settling process.

A suitable device should be placed at the feed end of the pond to distribute the flow evenly across its width thereby utilizing the full pond area. A similar device should also be placed at the discharge end. The ponds should be deep enough to prevent wave-action from stirring up the pond contents and to provide sufficient capacity to store accumulated solids. A depth of about 5 feet is the recommended minimum.

The major drawback to ponds of this type is the costs associated with the removal of accumulated solids. When used with a continuous manufacturing operation two ponds should be installed to allow one pond in operation while the other is being dewatered and cleaned. Dewatering and cleaning during the winter time is usually not practical. Cleaning schedules must, therefore, be carefully planned so work can be done in suitable weather.

Where degradable materials are settled-out, potential odour problems during warm weather can arise and the settled material may undergo anaerobic decomposition. To control against odours, the pH of the pond contents should be above 9. If this is done, it may be necessary to neutralize the contents before they are discharged to a watercourse.

In sandy soil, it is sometimes possible to construct sedimentation ponds from which there is no visible discharge: the wastes flow away by percolation through the sand into groundwater. From a treatment standpoint, this type of system has many advantages but test wells should be dug in the vicinity of such ponds to check for groundwater contamination. Figure 3-2 shows a typical sedimentation pond system.

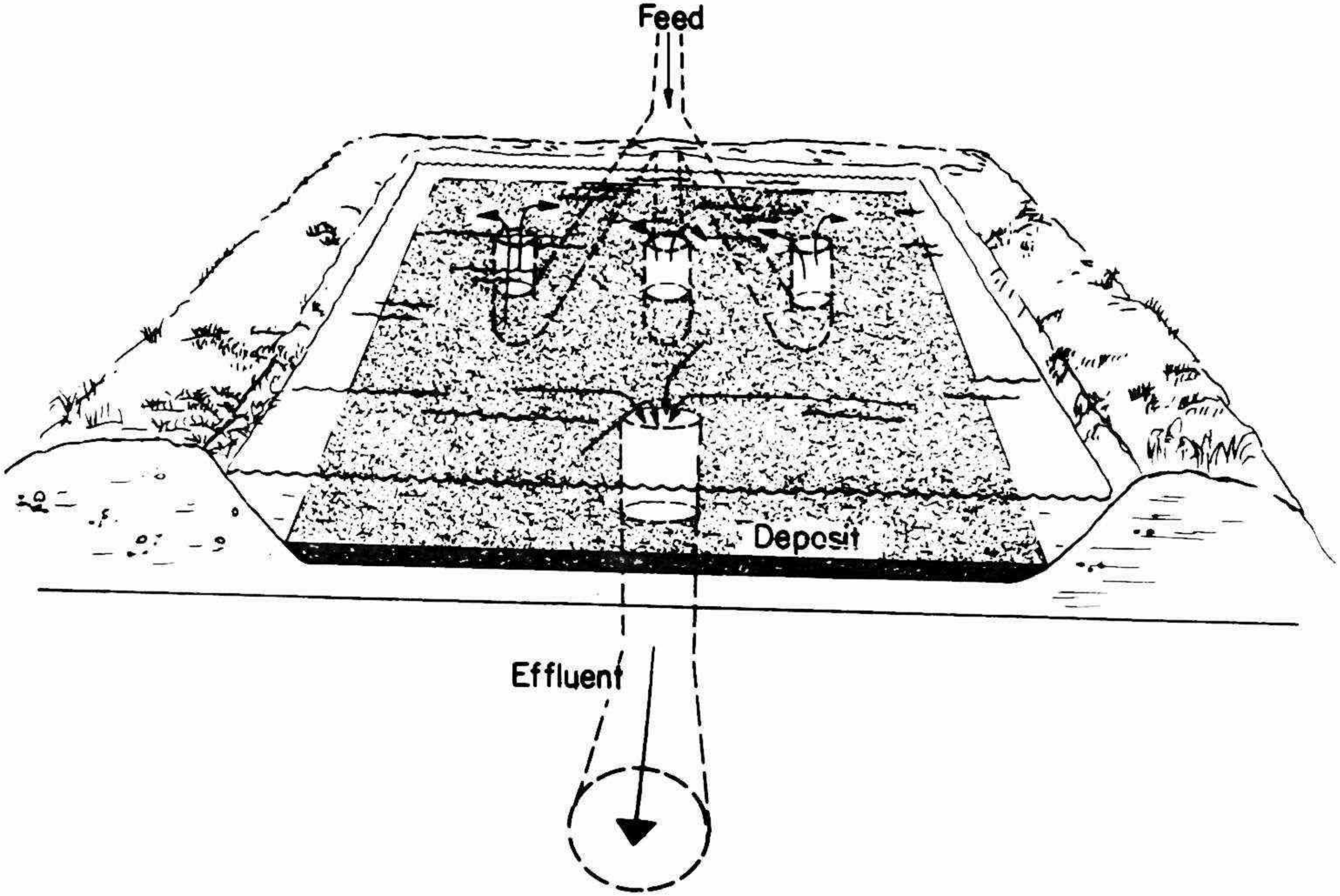


Figure 3-2
Typical sedimentation pond system

(b) Clarifiers

A clarifier is a suitably shaped vessel or earthen basin from which settled solids are continuously removed by mechanical means. Most clarifier basins are constructed of concrete or steel with the earthen basin normally reserved for large versions. Clarifiers are usually circular or rectangular.

The mechanism for removing the settled solids or sludge normally consists of a rake to move the sludge to a convenient point and a pumping system to pump the sludge to a disposal system. In the circular clarifier,the rake is pivoted at the centre and rotated by means of a central or peripheral drive. Sludge removal takes place from a central sludge well. Figure 3-3 shows the arrangement of a circular clarifier.

Circular clarifiers can be constructed to include a flocculating chamber in which fine, non-settling particles can be flocculated with the aid of chemicals. This type of clarifier is known as a "Reactor Clarifier". Also, gravity sludge thickening can be incorporated into the bottom of the circular clarifier. The purpose of this is to dewater the sludge as much as possible before removal from the clarifier. The nature of the solids being settled out will determine whether thickening should be incorporated.

In a rectangular clarifier, the rake is normally attached to an endless chain belt with the sludge being continuously moved to a sludge well at the feed end. Figure 3-4 shows the arrangement of a rectangular clarifier.

Sludge Dewatering

Sludge dewatering or thickening is vital, in most cases, to the satisfactory disposal of sludges and, as the term implies, its prime function is to remove water from the sludge. The sludge is conditioned and thickened enough to be burned or hauled away for land disposal. Economics will dictate the degree of water removal required. If the sludge is burned, the cost of removing water must be balanced against the fuel consumption of the incinerator or the fuel value of the sludge material. If the sludge is hauled away for land disposal, the cost of hauling water must be balanced against the cost of removing water.

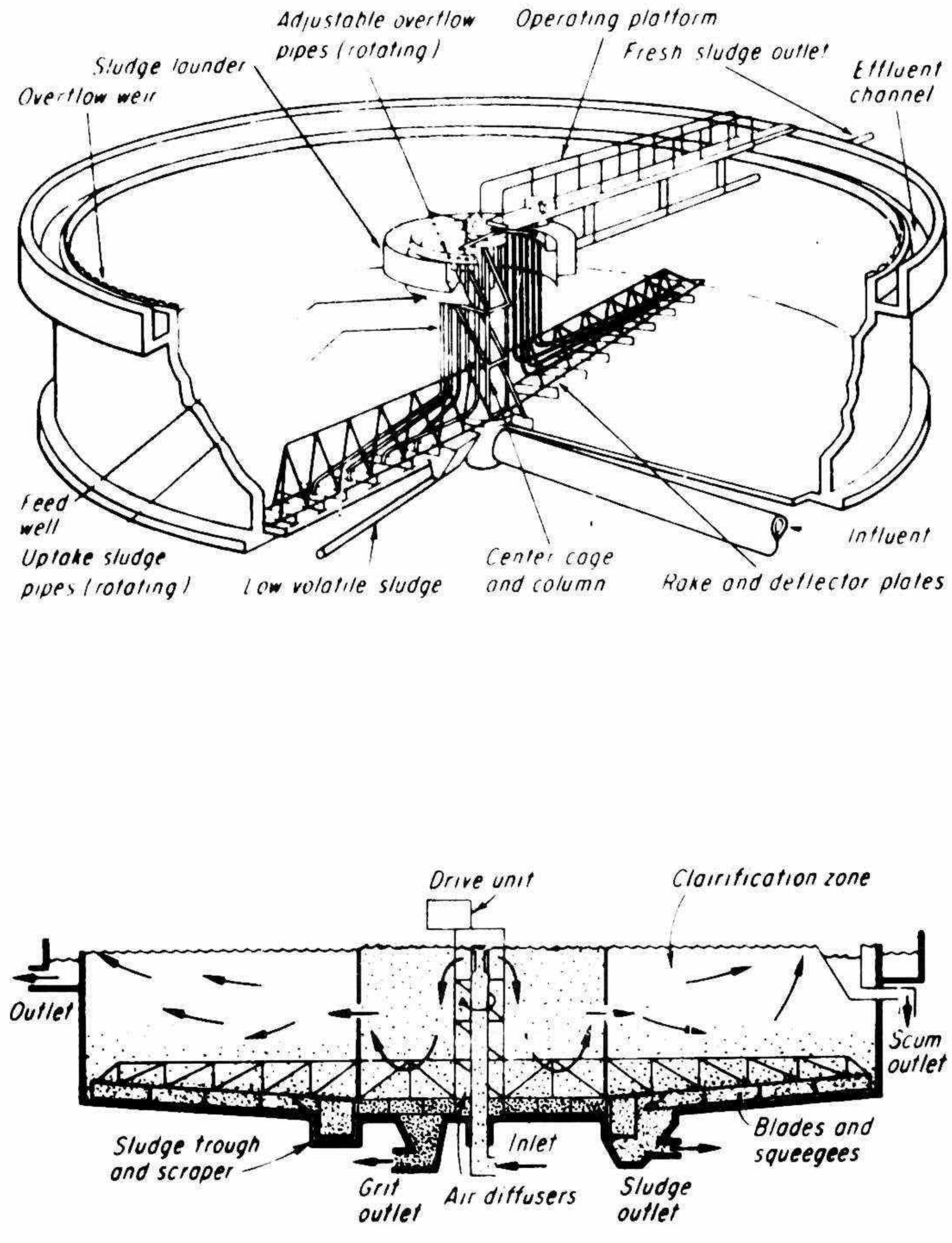


Figure 3-3
Circular Clarifier

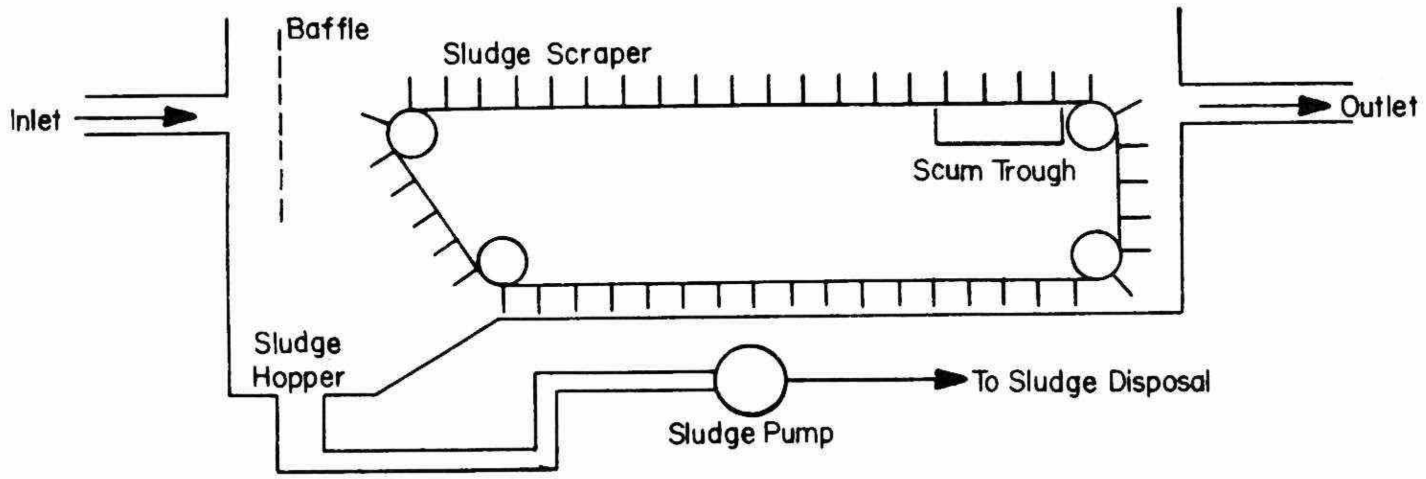


Figure 3-4
Rectangular clarifier

The most common methods used to dewater sludges are:

(1) gravity thickening;
(2) vacuum filtration;
(3) centrifuge.

The operating principles of the vacuum filter and centrifuge will be discussed later but the merits of each in application to sludge dewatering will largely depend on the characteristics of the sludge being dewatered. Gravity thickening is accomplished in a vessel similar to a clarifier. This provides the additional settling time required for the sludge to thicken. Rake mechanisms are generally stronger to accommodate the greater torque associated with the thicker sludges.

Centrifuges are manufactured in a variety of types and sizes for different application. The sedimentation centrifuge removes solids from liquids by causing the solid particles to settle through the liquid radially towards or away from the centre of rotation. Solids more dense than the liquid move outward and deposit on the surface of the bowl for removal by a suitable mechanism. Some designs do not allow the solids to deposit on the walls and continuously remove them through ports as a thick slurry. Generally, sedimentation centrifuges are small in diameter and operate at extremely high speeds.

Sedimentation centrifuges operate on a continuous liquid feed and discharge.

Figure 3-5 shows a horizontal, concurrent flow centrifuge, typical of the types used to separate large amounts of solids from liquids.

Because of their high speed operation, centrifuges are subject to maintenance problems. In particular, erosion of the internal vanes may occur if sandy or gritty particles are present in the solids. These problems can be overcome by the proper selection of materials of construction and strict adherence to operating instructions.

Solids removal by the centrifuge is not a very efficient process. The recovery of solids from the liquid decreases rapidly as the solids content of the slurry increases. Thus, the effluent or filtrate from the centrifuge is

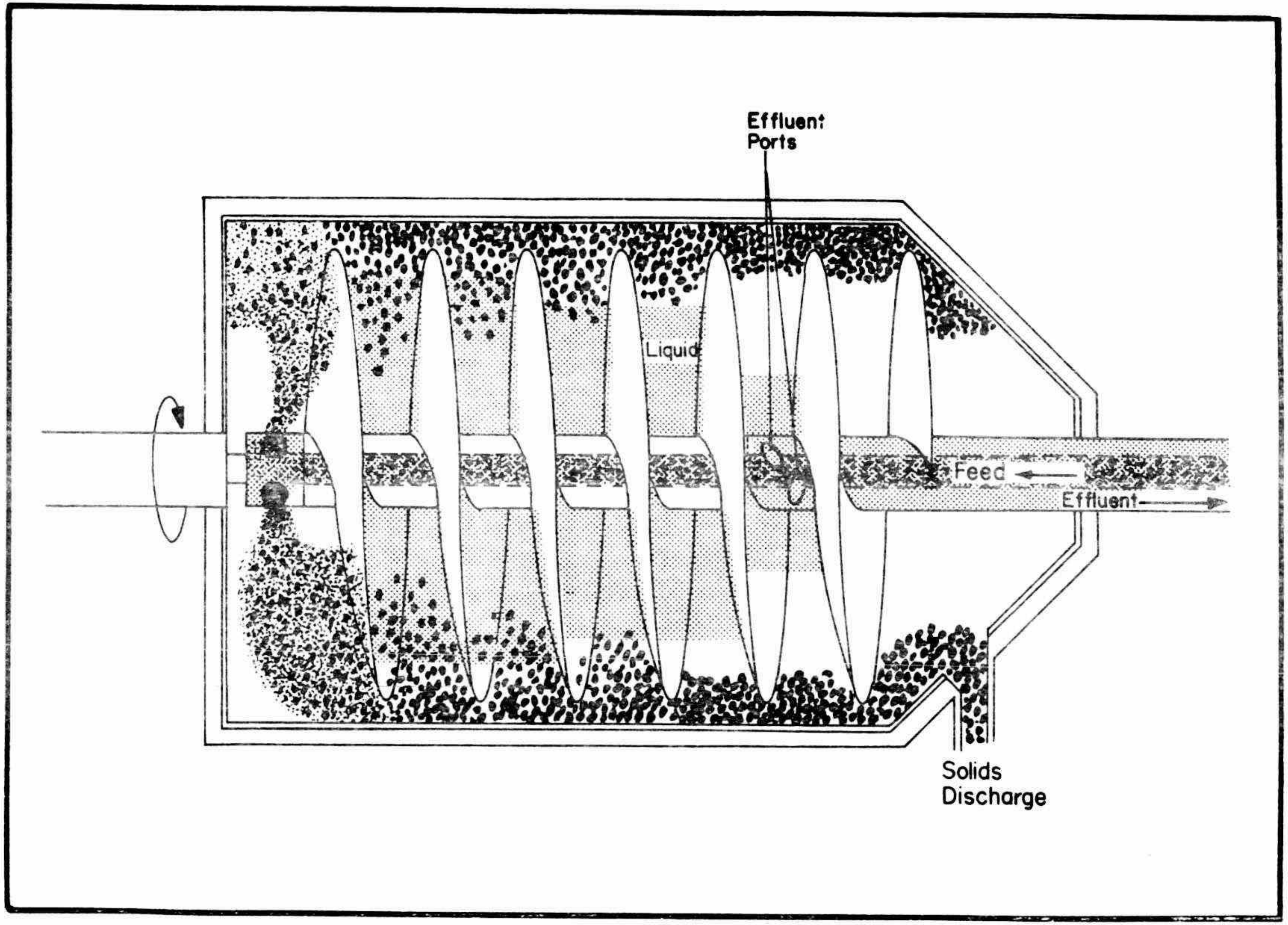


Figure 3-5
Concurrent Flow Centrifugal

usually not suitable for discharge to a storm sewer or watercourse although it may be suitable for discharge to a municipal sewer. To improve the solids recovery, flocculating chemicals can be added to the centrifuge feed. This increases the operating costs of the process.

The main advantage of the centrifuge is that it is a compact piece of machinery capable of handling high throughputs. It requires very little floor area when compared to a clarifier or settling pond.

Filtration

Filtration is the separation of suspended solids materials from a liquid through a membrane or medium that retains the solids on or within itself.

The clear liquid effluent resulting from the filtration process is called the filtrate. The solids accumulated on the membrane are known as the filter cake. Passage of the liquid through the membrane is by gravity, by pressure or by vacuum. This is one method of differentiating between filters. Other differences will depend on whether the filtering is a batch or continuous process and whether the prime function is to recover the solids or produce a clear filtrate.

Generally as the filter cake builds up and increases in thickness, the flow of liquid through the cake decreases to a point where it is too small to be of practical value. This problem is overcome by renewing the filter surface. Surface renewal is accomplished by the use of a rotary type filter, endless belt type filters or by stopping the filtration process and washing-off the accumulated cake. In a continuous operation, the cake is continuously removed and the filter membrane or medium is washed to present a new surface.

In a batch operation, the filter must be dismantled and the accumulated cake washed off, or the filter is back-washed using high pressure water. Filter backwashing can be automated either on a time cycle or pressure cycle. A series of batch filters having a common feed can be used on a staggered basis to provide continuous filtration.

The filter membrane or medium is composed of a variety of materials, but the most common is cloth. The composition of the cloth is selected for its resistance to chemical attack and its permeability. Wire cloths having a very fine mesh are also used. A cloth filter membrane is often unable to remove very fine particles by itself. It thus becomes necessary to build up a layer of some suitable porous material on the cloth to do the actual filtering. This process is known as precoating.

The filter medium may also consist of a bed of porous materials, such as sand, contained in a suitable vessel. This type of filter is frequently used in water treatment applications. Some comments on pressure and vacuum filters are as follows:

(a) Pressure Filters

Any filter operating under pressure to remove material is called a pressure filter. The pressure is normally provided by a pump or by compressed gas. Pressures in the range of 50 - 75 lbs./sq. inch are common and pressures as high as 500 lbs./sq. inch are in use.

Most pressure filters operate on a batch or intermittent basis. This is due to the difficulty of removing the cake from a pressurized environment. Some of the advantages claimed for pressure filters are:

(1) relatively rapid filtration occurs under high pressure. This allows difficult separations within practical time limits.

(2) due to their compactness, a large filtration area per unit of floor space is provided.

(3) they are flexible and have a relatively low initial cost.

The main disadvantage of pressure filters is the high *operating costs, usually associated with the high labour requirements.*

Figure 3-6 shows a pressure leaf filter.

(b) Vacuum Filters

Vacuum filters are those which operate with less than atmospheric pressure on the downstream side of the filter medium. The vacuum may be supplied by a mechanical vacuum pump, an ejector system or by providing a seal on the barometric leg. In effect, the liquid is sucked through the filter medium by the vacuum. The upstream pressure is normally atmospheric. The vacuum filter is thus limited to a maximum filtering pressure of approximately 1 atmosphere or 14.7 lbs./sq. inch.

The filtrate from a vacuum filter will be at the pressure of the vacuum. It will require compression before discharge from the filter. This is accomplished either by using a barometric leg or a filtrate pump.

The advantages and disadvantages of vacuum filters are listed below:

(a) Advantages

- *they can be designed as effective continuous filters and, as such, can be employed readily in continuous processes.*
- *they have low labour requirements.*
- *the filtering surface can be open to atmosphere and, therefore is easily accessible for inspection and maintenance, even during operation.*
- *maintenance costs are relatively low.*

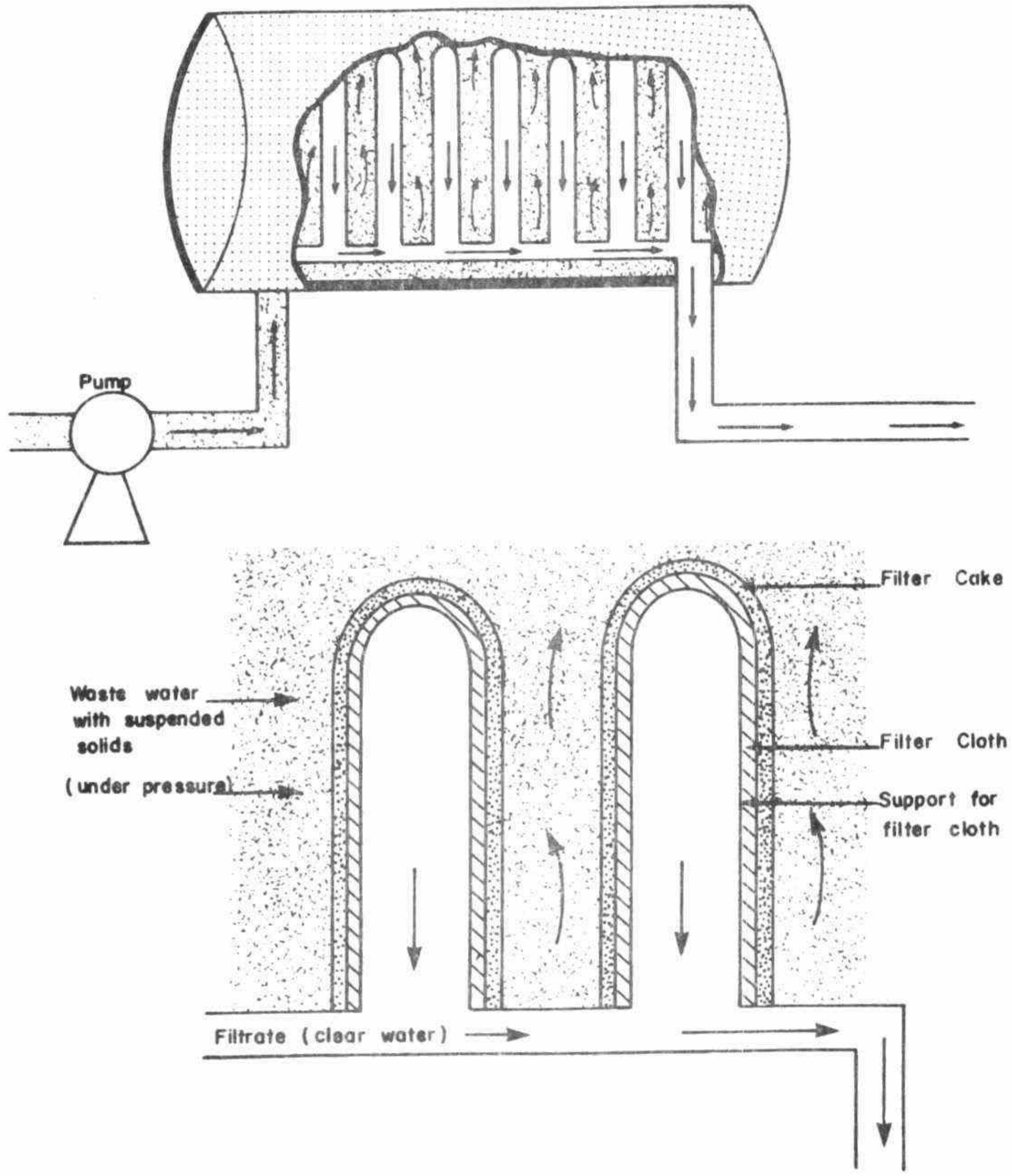


Figure 3-6
Pressure Filter

(b) Disadvantages

- a vacuum system must be provided and maintained.
- the filters cannot be used with filtrates that are volatile because of low boiling point or high operating temperatures.
- they are inflexible and do not perform well if the feed stream changes with respect to rate, consistency or character of solids.

Two types of vacuum filter are in common use. These are the rotary filter and the disc filter.

Rotary Filter

In the rotary filter, the filter medium covers the surface of a cylindrical drum which rotates on a horizontal axis and which is immersed in a batch of the liquid to be filtered. The inside of the drum is compartmentalized into segments to which a vacuum may be applied and then released as the drum revolves. The filtrate passes to the inside of the drum and is removed by some suitable device. The solids are released from the filter medium either by blowing-off with air, by scraping off with a doctor knife, or merely by allowing them to fall off as the filter medium passes over and under a set of rollers.

Disc Filters

The disc filter works on a similar principle except that the filter is made up of a number of discs attached to a common rotating horizontal shaft such that the discs rotate in a vertical plane. Both sides of the discs are covered with filter medium and the inside of each disc is segmented as in the case of the rotary filter. Removal of accumulated cake is normally accomplished by blowing with air.

Figure 3-7 shows schematically the arrangement of a rotary drum filter.

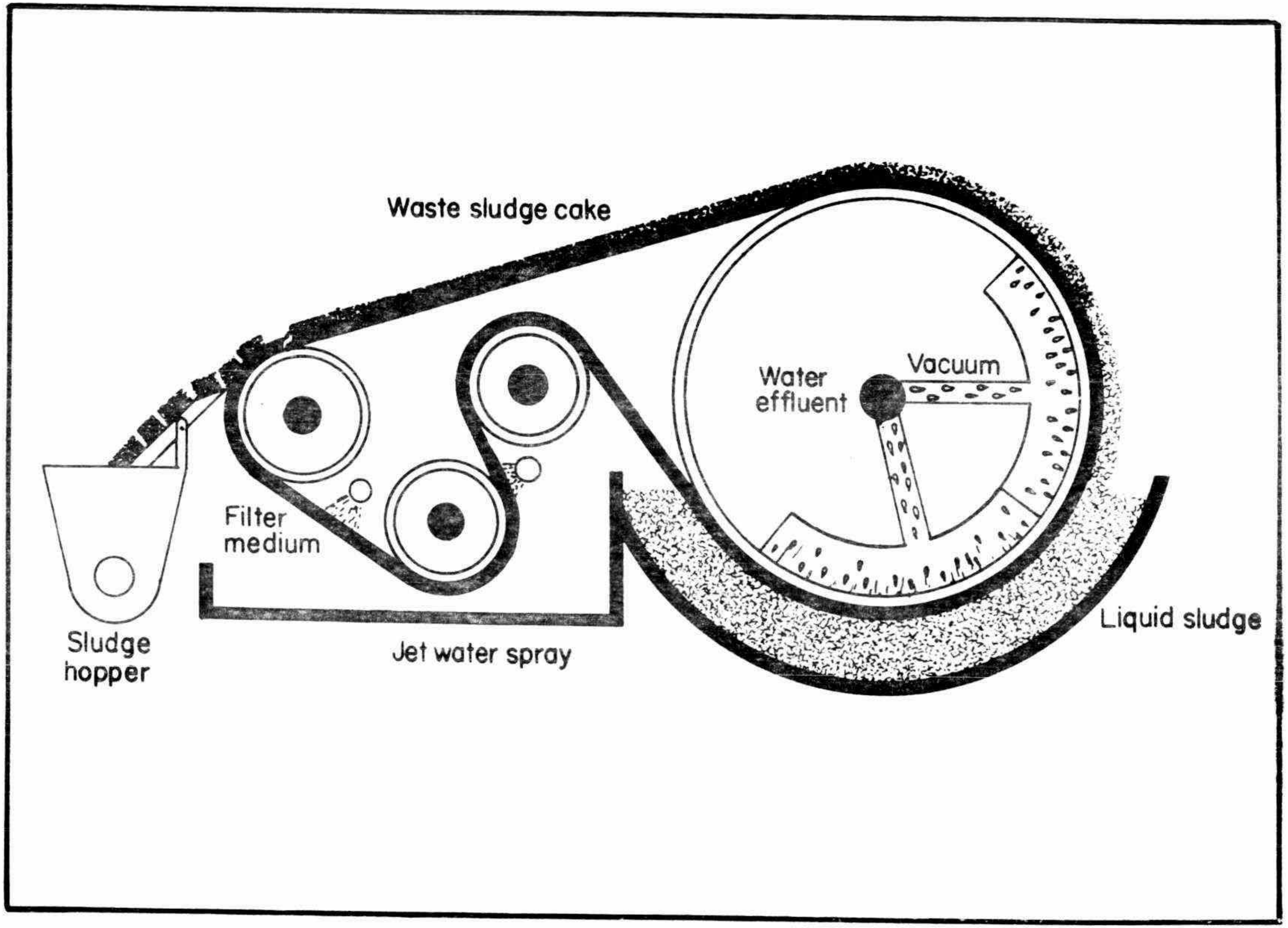


Figure 3-7
Rotary Drum Filters

As mentioned earlier, filters are made in a variety of types and sizes. Only a few of these have been mentioned here. The two most important factors when selecting a filter for a specific suspended solids removal problem are the clarity of filtrate required and the relative cost of achieving this clarity.

Flotation

Separation of suspended solids from a liquid by flotation is effected by introducing very fine bubbles of air into the solid-liquid mixture at a point below the surface. As air bubbles rise, they are either trapped by the particle or adhere to it. This increases the buoyancy of the particle to the point where it will float to the surface. The accumulated particles on the surface can then be removed by some suitable means. To improve flotation a variety of chemical additives is used. They coagulate the solid particles to promote more stable bubbles and lower the surface tension between the solids and the liquid.

A Dissolved Air Flotation system is used in the waste treatment field (Figure 3-8). As the name implies, dissolved air flotation operates on the principle of dissolving air into water under pressure. When the pressure is released, minute bubbles of air are formed in the water which carry solids in suspension with them as they float to the top. The advantage of this type of system is that the air bubbles are much smaller than any produced by mechanical means.

To conserve chemicals, a portion of the effluent is recycled from the flotation tank and pressurized using air. This minimizes the risk of breaking-up flocculent particles in the waste feed as these do not pass through the aeration pump.

Flotation units are not very flexible. They require uniform feed rates and characteristics. Their ability to handle surges of suspended solids is limited.

CHEMICAL TREATMENT

Included with chemical treatment is neutralization and pH

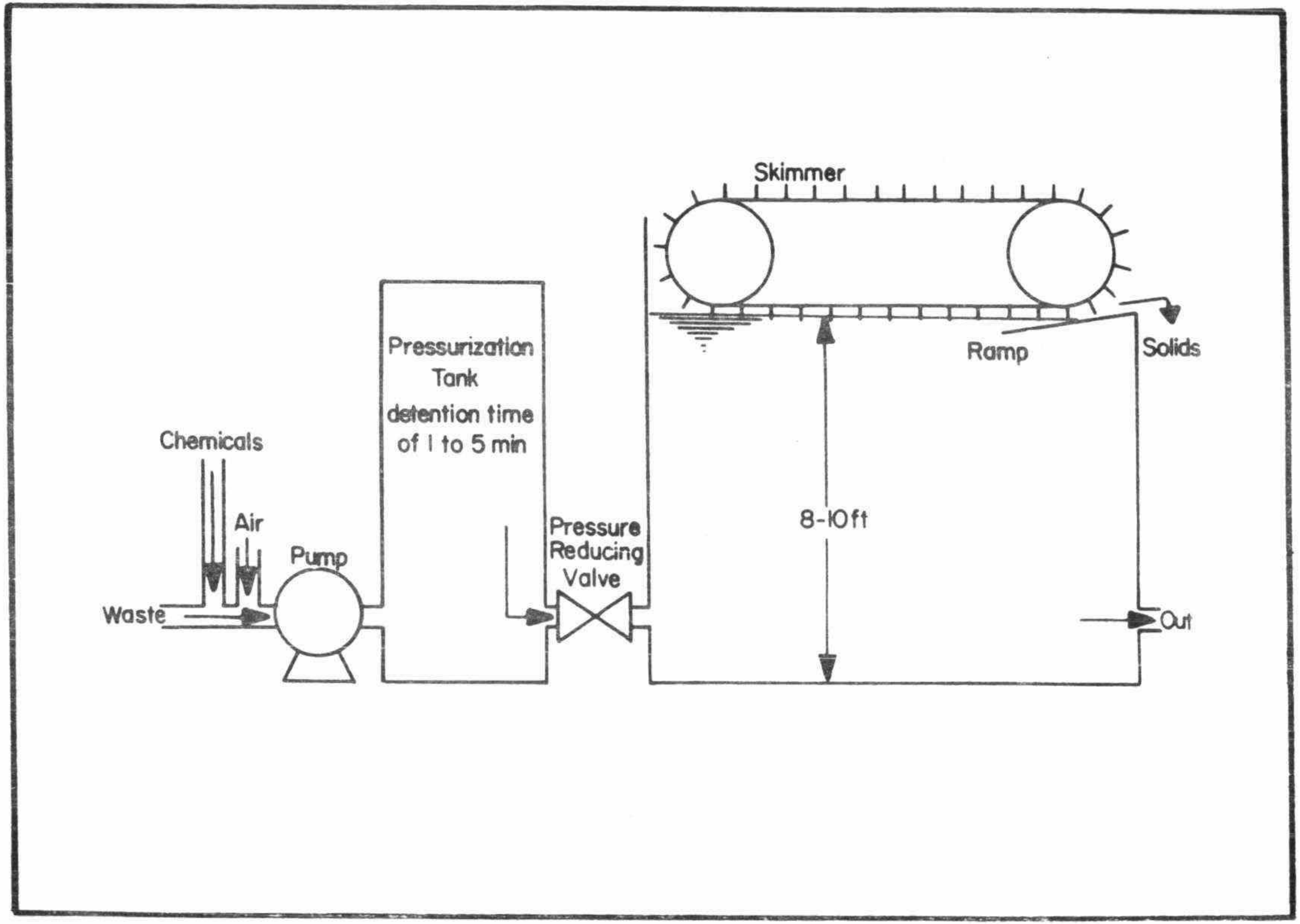


Figure 3-8
Dissolved Air Flotation System

control. With most treatment systems, neutralization and pH control is a prerequisite. In municipalities, maintain the pH of wastes being discharged to sewers within the range specified by the by-law. This insures protection for the municipal sewers.

Neutralization and pH Control

Neutralization involves the raising or lowering of the pH of a waste stream to the neutral point which occurs at a pH of 7. pH control maintains the pH at any desired value within the range 0 - 14.

Figure 3-9 shows a typical neutralization or pH control system.

A pH sensor measures the pH of the final effluent. At the same time, it controls the rate of feed of chemicals to a well mixed retention vessel. The retention vessel provides mixing of chemical with waste for pH control. The vessel is omitted if adequate mixing of chemical and waste can be ensured by other means such as turbulent flow in a long length of pipe.

In practice, pH control systems are unsatisfactory unless they are extremely well maintained and checked at frequent intervals. The pH probe tends to become readily fouled with deposits of materials and requires very frequent cleaning for good control.

A variety of chemicals can be used to provide the desired acid, alkaline or neutral state. These chemicals can be fed in the solid, liquid or gaseous form. The liquid and gaseous forms generally provide a more satisfactory system. The feeding of solid materials at prescribed rates tends to be difficult for continuous operation. Some of the more common chemicals used in the control of pH are listed below:

(1) Solids: slaked lime (calcium hydroxide)
calcium carbonate
soda ash (sodium carbonate)
alum
magnesium oxide.

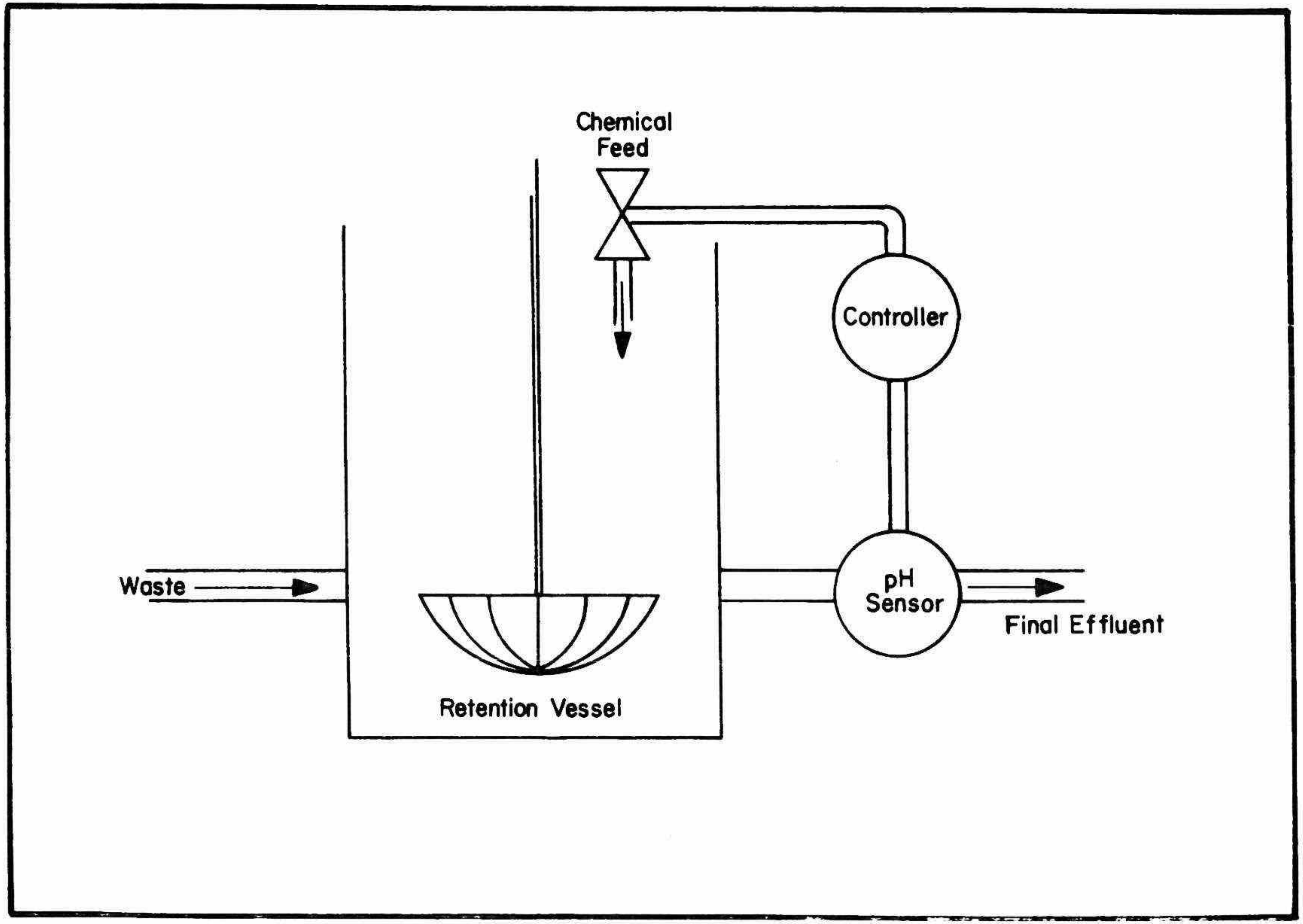


Figure 3-9
pH control system

(2) Liquids:
- slaked lime slurry (calcium hydroxide)
- caustic soda solution (sodium hydroxide)
- ammonium hydroxide
- liquid ammonia
- sulphuric acid
- hydrochloric acid
- nitric acid
- liquid sulphur dioxide
- liquid chlorine

(3) Gases:
- chlorine
- sulphur dioxide
- ammonia

The choice of chemical used will depend on the nature of the wastes, the size of the system and the economics.

Precipitation

Some chemical compounds have a very low solubility in water. This can frequently be used as a method of removing certain materials from a solution. For example, many of the solids of hydroxides of metals are relatively insoluble under specific pH conditions. By the addition of alkaline materials, these insoluble solids are formed and can be removed from the water by sedimentation or filtration.

The phosphate removal systems presently being installed in many municipal sewage treatment plants are working examples of the use of precipitation to remove an undesirable material, in this case phosphate. By the addition of lime (calcium hydroxide), alum or ferric chloride, phosphate can be precipitated out as calcium phosphate, aluminum phosphate or ferric phosphate. (Actually the compounds formed are not simple phosphates but the above serves to illustrate the principles of the process).

Examples of waste substances that can be precipitated from solution by the formation of an insoluble compound and then removed by sedimentation or filtration are given in Table A.

It must be stressed that conditions under which the precipitates are formed as readily settleable or filterable materials are often very critical, particularly with respect to pH.

TABLE A

Removal of Soluble Substances by Precipitation

Substance	Precipitating Agent	Precipitate Formed
Nickel	Sodium or Calcium Hydroxide	Nickel hydroxide
Chromium	"	Chromium hydroxide
Copper	"	Copper hydroxide
Iron	"	Iron hydroxide
Mercury	Sodium sulphide or hydrogen sulphide	Mercury sulphide
Lead	"	Lead sulphide
Radium	Barium chloride/ sulphate	Radium chloride/ sulphate
Phosphate	Calcium hydroxide	Calcium phosphate
Sulphide	Lead nitrate	Lead sulphide
Chromate	Barium carbonate	Barium chromate
Bicarbonate	Calcium hydroxide	Calcium carbonate

The most common applications of precipitation occur in the plating industry. Removal of mercury by precipitation as mercuric sulphide is also the accepted method of treating effluents from the chlor-alkali industry.

Cyanide Destruction by Alkaline Chlorination

Cyanides are used widely in the metal processing industries for metal plating, case hardening of steel and the refining of gold and silver.

Cyanides are extremely toxic, particularly under acidic conditions where they will form hydrogen cyanide.

In the alkaline chlorination treatment process, cyanides are oxidized by the addition of chlorine in the presence of sodium hydroxide to form sodium cyanate.

The cyanate produced is only one one-thousandth as toxic as cyanide and will break down to yield ammonia and carbon dioxide. Further addition of chlorine and caustic soda will oxidize the cyanate to carbon dioxide and nitrogen.

Reactions are complete in about 10 minutes at pH 8.5.

The process can be conducted either in batch or continuous treatment systems. Figure 3-10 shows an Instrumented Batch Cyanide Treatment System.

BIOLOGICAL TREATMENT

Biological treatment systems have been used in the treatment of domestic sewage since the early 1900's. In recent years, this type of treatment has found increasing use in the treatment of industrial wastes and is now an accepted part of industrial waste control.

The lower forms of life or microbiota such as bacteria and fungi, require much the same basic materials as human beings in order to grow and flourish. In particular, readily available sources of carbon, nitrogen and phosphorus are required. Bacteria must obtain these vital elements from the waters in which they live. These elements must be

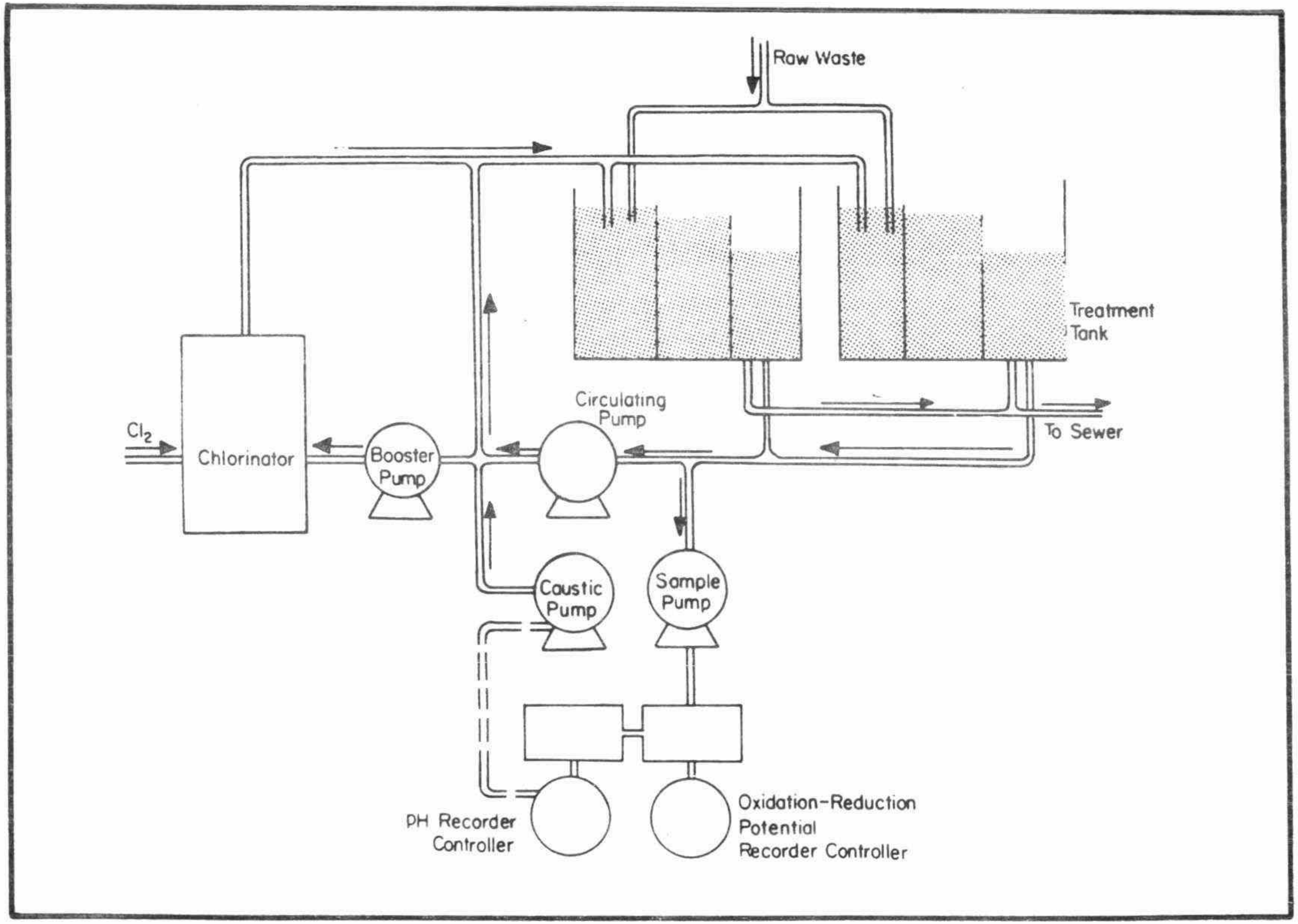


Figure 3-10
Instrumented Batch Cyanide-Treatment System

present in the waters in a dissolved state so that the bacteria can ingest them through their cell walls.

One ready source of carbon is the waste materials from many manufacturing and processing operations. In fact, anything which we arbitrarily call organic can be utilized as a source of carbon by some bacteria eventually. Thus, all organic substances can be broken down by the action of bacteria and fungi. In order for these organisms to utilize the organic materials as food, certain conditions must prevail in the local environment.

Firstly, nitrogen and phosphorus must be present and available, and necessary trace elements, mostly metals, must also be available. Secondly, certain basic elements such as oxygen, sulphur or iron must be present, depending on the types of bacteria, if the bacteria are to utilize the food source.

Bacteria, fungi, yeasts, algae, etc., generally fall into one of two categories:

(a) those requiring elemental oxygen in order to carry out their metabolic processes (aerobic organisms).

(b) those that can carry out their metabolic processes without the presence of elemental oxygen but which require compounds containing oxygen such as sulphate, nitrate or carbon dioxide to be present (anaerobic organisms).

Some organisms can adapt to both situations. These are basically aerobic organisms but they have the ability to grow anaerobically when the need arises and are known as facultative organisms.

These two basic types of bacteria permit development of two basic types of biological treatment:

(a) Aerobic treatment in which

oxygen has to be supplied.

(b) Anaerobic treatment in which oxygen is not required or in which it is excluded.

There is a third type of treatment which utilizes both types of bacteria and this is generally classified as facultative.

One problem arising out of biological treatment is the production of solids or cell mass. For each unit of BOD removed by bacterial action approximately 40 - 50 percent by weight is converted into new cell mass (new bacteria) and the remainder is oxidized to carbon dioxide and water. It is the oxidation process that provides the energy necessary for the bacterial cells to carry on their functions of living and also to reproduce and create new cell material.

If the food supply to the bacteria is stopped, the cells will undergo auto-oxidation in which approximately 60 percent of the newly created cell mass will be oxidized to provide the energy requirements for the remaining cells. Thus, the minimum amount of new cell mass created in a biological oxidation system is about 20 percent of the feed BOD. However, to accomplish this, the food supply must be limited and cause the bacteria to go into a state known as endogenous respiration.

If removal of these 20 percent solids is required, it must be accomplished by anaerobic decomposition.

The selection of a particular system will depend on many factors, including the ease with which the waste can be degraded, its characteristics, the volume of waste to be treated, the availability of land, the degree of treatment required, fluctuations in waste volumes and loadings, and cost.

(a) Aerobic Biological Treatment Systems

The following list indicates the common aerobic biological treatment systems available:

(i) Stabilization lagoon or pond.

(ii) Aerated facultative lagoon.

(iii) Activated sludge and extended aeration - oxidation ditch.

(iv) Contact stabilization.

(v) Trickling filter.

(i) Stabilization Lagoon

Stabilization lagoons are very common for the treatment of domestic sewage where land is available. There are two types of lagoons: (1) the total retention lagoon from which there is no discharge for most of the year, with the lagoon contents being discharged only during periods of high stream flow in the receiving stream (Spring), and (2) the flow-through system type of lagoon.

Lagoons are normally constructed to operate with liquid depths of 3-6 feet and designed on a basis of 20 pounds of BOD_5 *per acre of surface area per day. Because of the relatively large land requirement, stabilization lagoons are limited to industrial applications having low daily volumes or to seasonal applications such as the canning industry.*

Oxygen requirements for the bacterial oxidation processes are supplied by oxygen transfer from the air through the water surface, or by the activity of algae in sunlight, or a combination of both. Often an anaerobic layer develops on the bottom of the pond and the pond then becomes facultative. Solids produced by bacterial oxidation will settle to the bottom and undergo anaerobic decomposition producing methane, hydrogen sulphide and other gases. Odour will be produced if the aerobic layer is not maintained.

Figure 3-11 shows a cross section of a facultative stabilization basin.

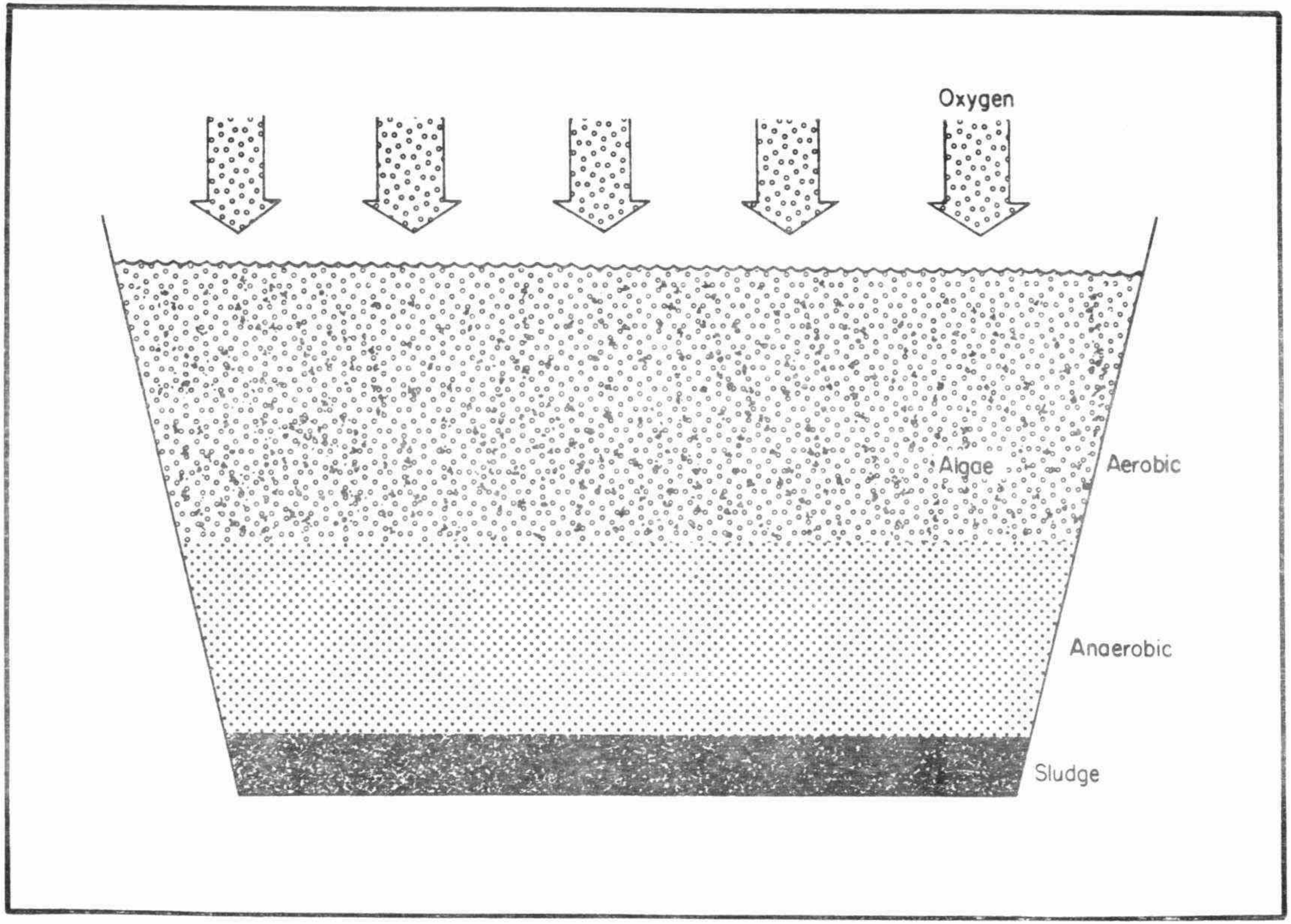


Figure 3-11
Faculative Stabilization Basin

(ii) Aerated Facultative Lagoon

The aerated facultative lagoon is similar to the facultative stabilization basin except that oxygen is supplied to the lagoon by some suitable means such as diffusers or mechanical surface aerators. Because oxygen requirements can be satisfied much more readily and considerable mixing takes place, these systems can handle greater loadings of applied BOD. They are, therefore, relatively smaller in surface area than the stabilization basin and can be operated at depths of 10 - 15 feet. The mixing, however, must not be too violent to prevent the decomposition of solids.

The applied BOD_5 to the lagoon should be limited to a maximum of about 3 pounds per 1,000 cubic feet of lagoon volume (3 lbs. $BOD_5/1,000\ ft^3$). The lagoon can handle substantial shock loadings without any severe reduction in the quality of the treated effluent.

(iii) Activated Sludge Process

In this process, the oxygen requirements of the microorganisms are met by mechanical means in an aeration basin. Solids or cell mass produced are removed subsequently in a clarifier, known as the secondary clarifier. A portion of the solids is recycled to the aeration basin from the clarifier and mixed with the incoming raw sludge. The remainder is wasted either to the digestion process, or to final disposal.

Figure 3-12 is a schematic of a conventional activated sludge process.

The process works over a wide range of applied BOD_5 loadings but it is limited to producing solids that will flocculate and settle readily. A conventional system operates with an applied BOD_5 loading rate of 30 - 35 lbs. BOD_5 per 1,000 ft^3 of aeration tank. High-rate systems have been developed that operate with loadings in the range 400 - 500 lbs. $BOD_5/1,000\ ft^3$ of aeration tank. The minimum recommended detention time in the aeration tank is one hour.

A modification of the activated sludge system is the "Extended Aeration System". In this system, the bacteria are allowed to go into the endogenous respiration phase

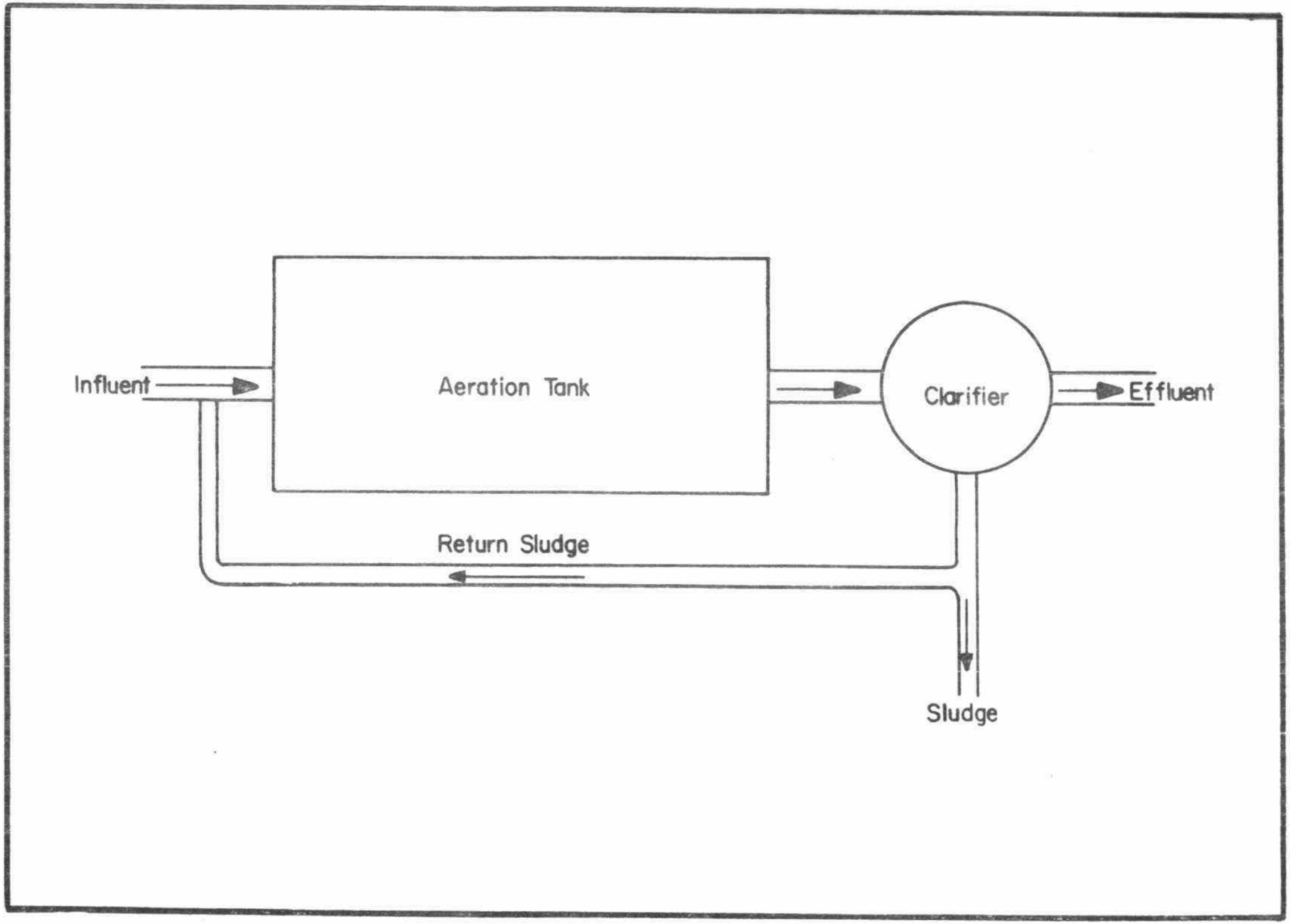


Figure 3-12
Conventional Activated Sludge Process

to minimize the production of solids. This is accomplished by providing additional aeration time.

The oxidation-ditch is an example of an extended aeration plant and is shown schematically in Figure 3-13. Secondary clarification is still required although the amount of sludge generated is less.

Table B indicates some typical design and operating parameters for activated sludge plants.

(iv) Contact Stabilization Process

The contact stabilization process functions on the ability of activated sludge to absorb materials and is particularly useful when a large portion of the BOD_5 is in the suspended or colloidal form. Figure 3-14 is a basic schematic of the process.

The feed waste is mixed with activated sludge in an aerated contact basin having a retention time of 20 - 40 minutes. The activated sludge absorbs organics and is then separated from the liquid in the secondary clarifier. Some of the separated sludge is wasted but most is passed to a reaeration tank where the sludge is reaerated for a period of 1.5 to 5 hours. During reaeration, the organics absorbed by the sludge are utilized and the sludge is stabilized and reactivated. This process permits a reduction in overall aeration basin capacity.

(v) Trickling Filters

The trickling filter consists of a packed bed of suitable material through which the wastes being treated flow. Sufficient voids between the packing allow air to pass upwards. A film of biological sludge grows on the surface of the packing, using the organics from the wastewater as a source of food and energy. As the mass of slime grows on the surface, it reaches a point when it can no longer hang on and breaks away from the packing surface. Thus, the slime growth is constantly renewed. Secondary clarification of the effluent is necessary to remove the biological solids produced in the filter.

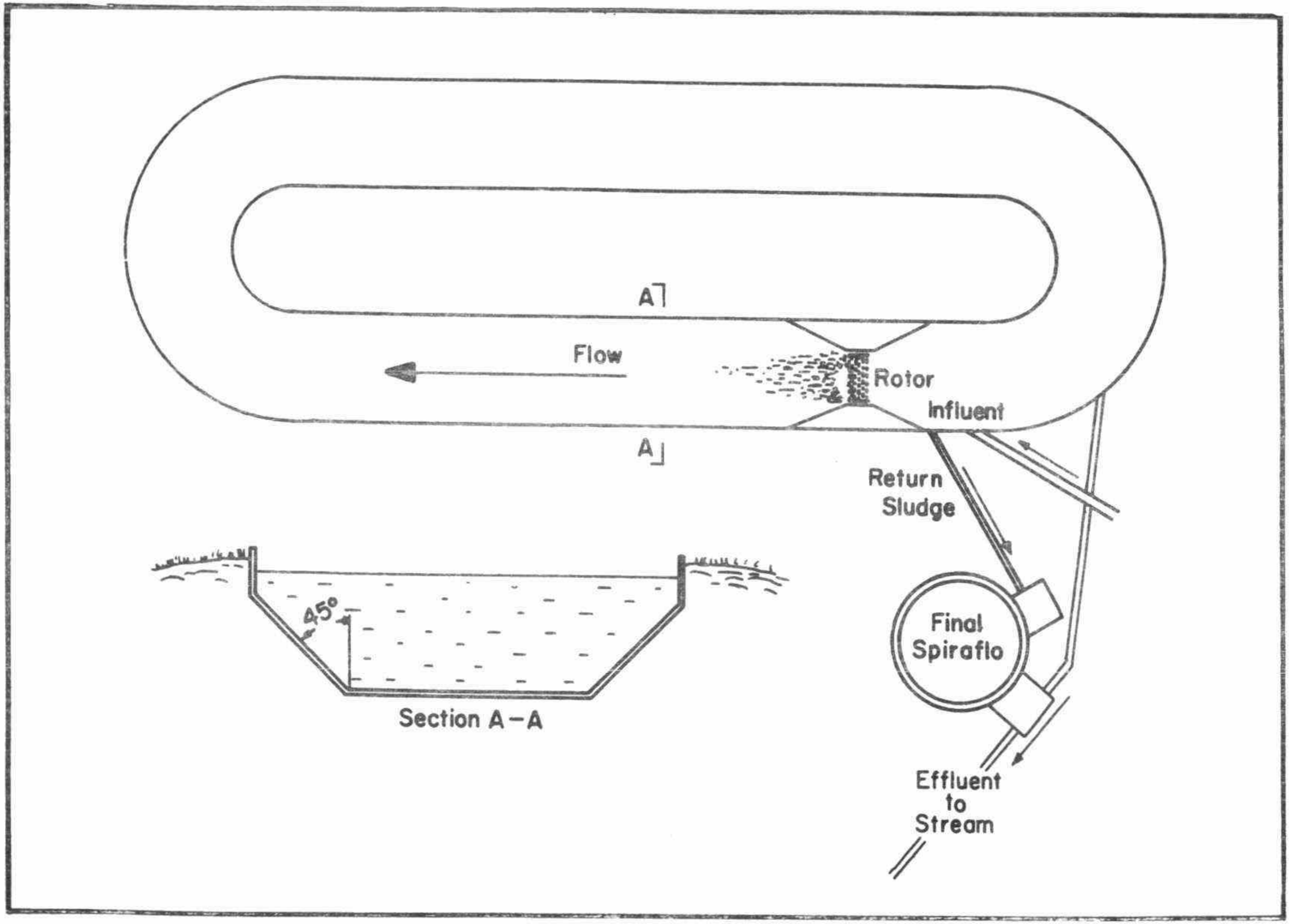


Figure 3-13
Oxidation ditch

TABLE B

Activated Sludge Parameters

	Conventional	Extended Aeration
detention time in aeration tank - hrs	4 - 8	15 - 30
volumetric loading - $\frac{\text{lbs BOD}_5}{1{,}000\ \text{ft}^3}$	30 - 35	12 - 25
BOD Removal efficiency	85 - 95	$>$ 95
Effluent quality - mg/l BOD_5	20 - 30 mg/l	$<$ 20 mg/l

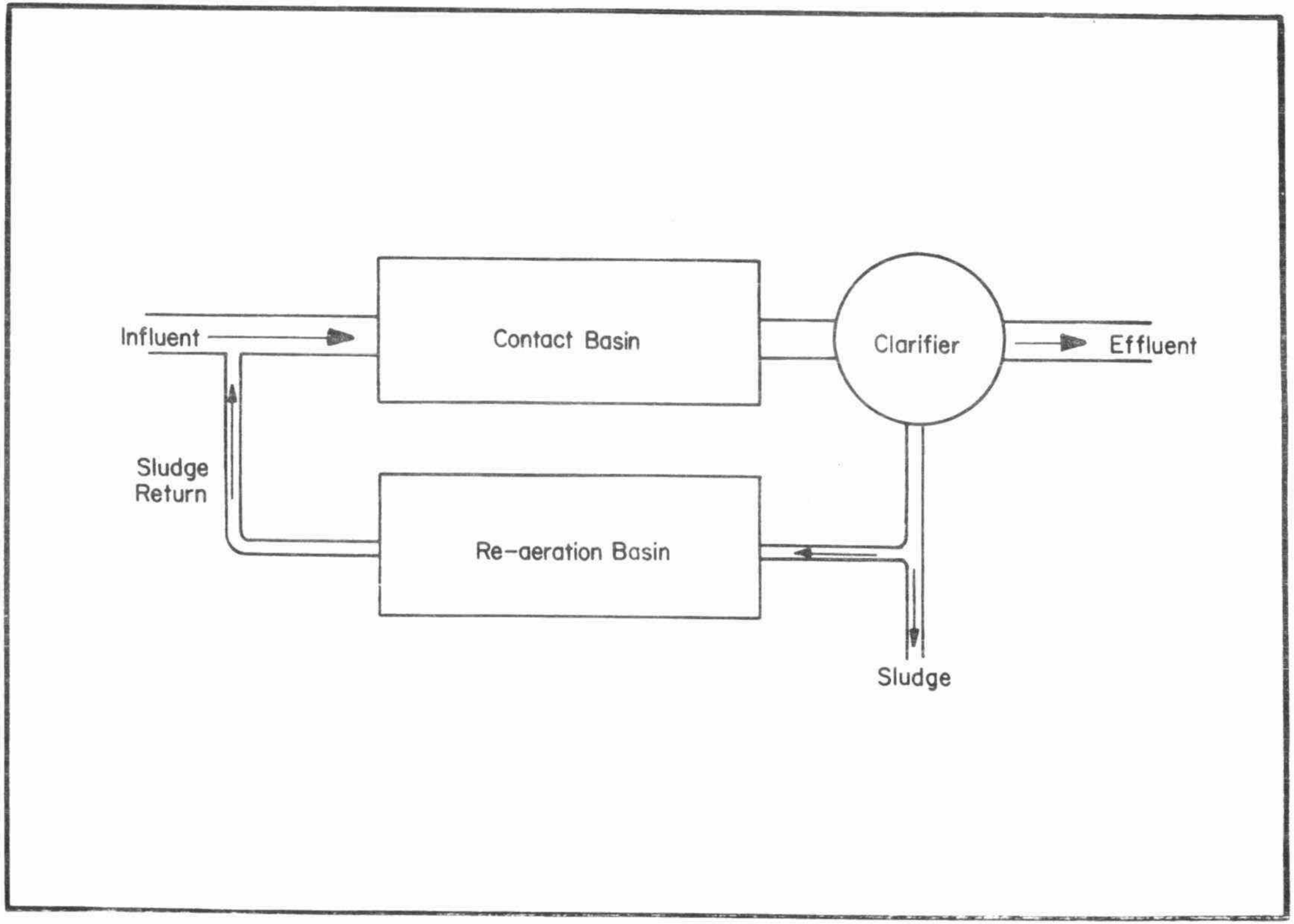


Figure 3-14
Contact Stabilization Process

The filter medium or packing may be any suitable material; generally graded crushed rock of 2" - 4" size is used. The depth of the rock bed may range from 3 feet to 8 feet, with the depth being governed by the soil bearing characteristics. Synthetic media are now available which are much lighter in weight than rock, making it possible to construct filters up to 50 ft. in height. However, the plastic media tends to cost more than the crushed rock. Figure 3-15 shows a rock bed trickling filter.

Trickling filters may be operated (a) on a once-through basis, (b) with recycle of effluent, (c) and in series. BOD_5 removal efficiencies can range as high as 80 percent, although generally they will be somewhat lower. Trickling filters are usually less costly to build than conventional activated sludge plants.

Trickling filters have not been used extensively in Canada on industrial waste applications because of poor treatment efficiency during cold weather periods. However, the new plastic media allow for more compact, enclosed designs and the use of the filter may increase.

(b) Anaerobic Biological Treatment Systems

Anaerobic biological decomposition is the conversion of organic wastes to gases (methane and carbon dioxide) without the presence of free (elemental) oxygen. The conversion of organic compounds to methane gas yields very little energy, resulting in a slow growth rate and a relatively small yield of biological solids or sludge. The rate of process reaction can be increased by raising the temperature; it is possible to obtain 80 - 90 percent conversion of organics to gas. The methane gas can be collected and utilized to provide heat for the process.

Two types of anaerobic process systems are commonly encountered:

(i) the anaerobic lagoon
(ii) the digester

Of these, the anaerobic lagoon is the system most commonly used in the treatment of industrial wastes. The digester is used almost exclusively as a method of stabilizing the sludges generated by aerobic treatment of municipal and industrial wastes.

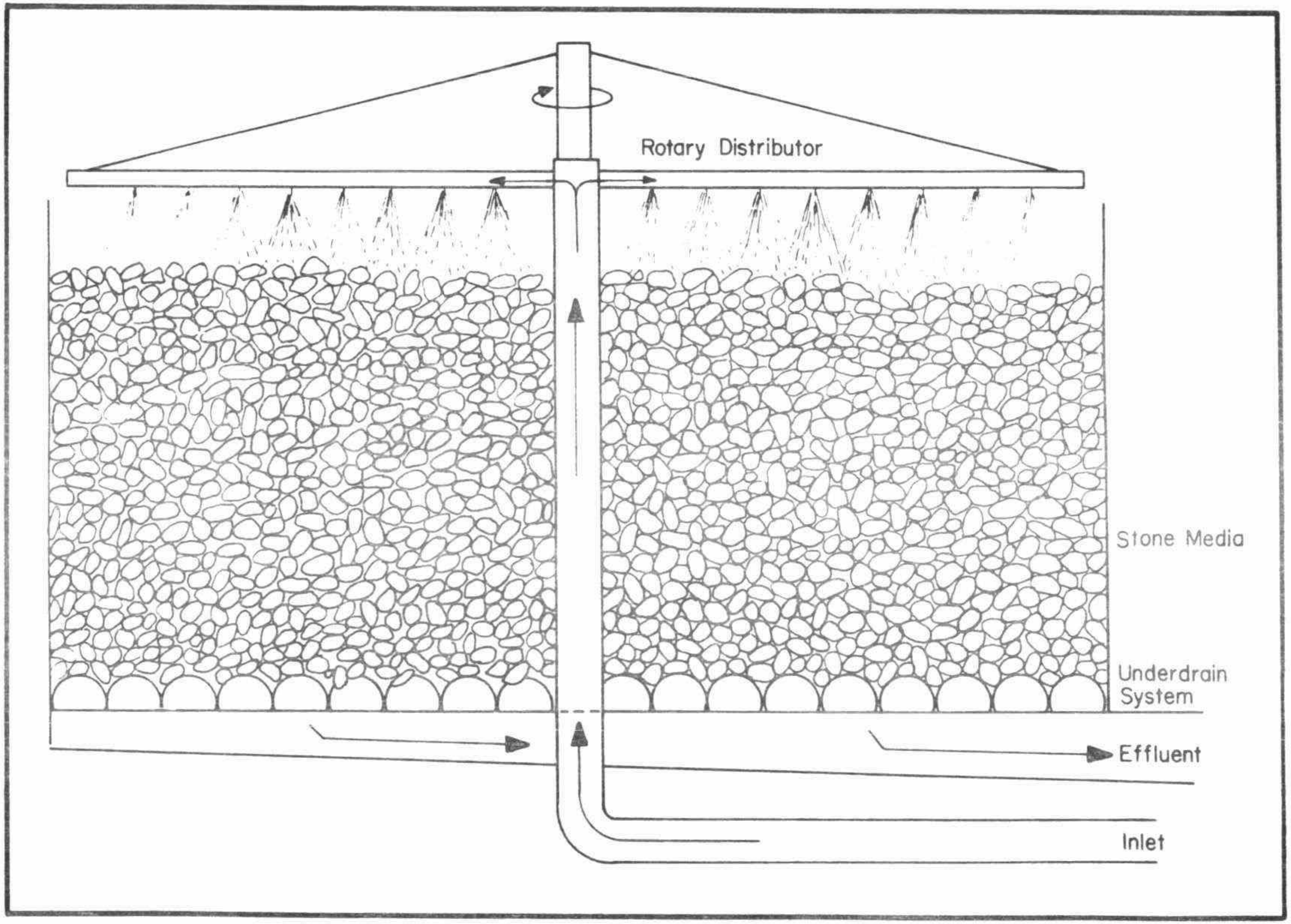


Figure 3-15
Trickling Filter

(i) The Anaerobic Lagoon or Stabilization Pond

An anaerobic lagoon is designed to give a minimum surface area-to-volume ratio which provides maximum heat retention and minimum oxygen transfer. The waste is fed to the pond at a rate that maintains anaerobic conditions throughout the liquid volume. The following table presents some of the common design parameters for anaerobic lagoons:

Anaerobic Lagoon - Design Parameters

Depth, ft.	8 - 10
Detention, days	30 - 50
BOD loading lb/acre/day	300 - 500
Percent BOD removal ..	50 - 70

(ii) The Anaerobic Digester

Figure 3-16 shows a schematic of a typical digester.

Certain concentrated industrial wastes can contain materials that are toxic to the digestion process. These include most of the metallic ions, particularly the heavy metals, ammonia, sulphides and numerous organic compounds. Do not overlook these possibilities when considering digestion as part of the process. During operation, digester temperatures are normally maintained in the range of $85^{o}F$ to $100^{o}F$ and pH is maintained near the optimum of 7.

(c) Irrigation

A further method of biological treatment that is relatively cheap and convenient, if land is available, is irrigation. Irrigation involves the distribution of wastes over the land so the liquid will percolate through the soil and be treated by the soil bacteria. Depending on the type of wastes, the type of soil and the topography of the land, it can be practised in a number of ways:

(1) Spraying over relatively flat land by the use of irrigation type spray nozzles.

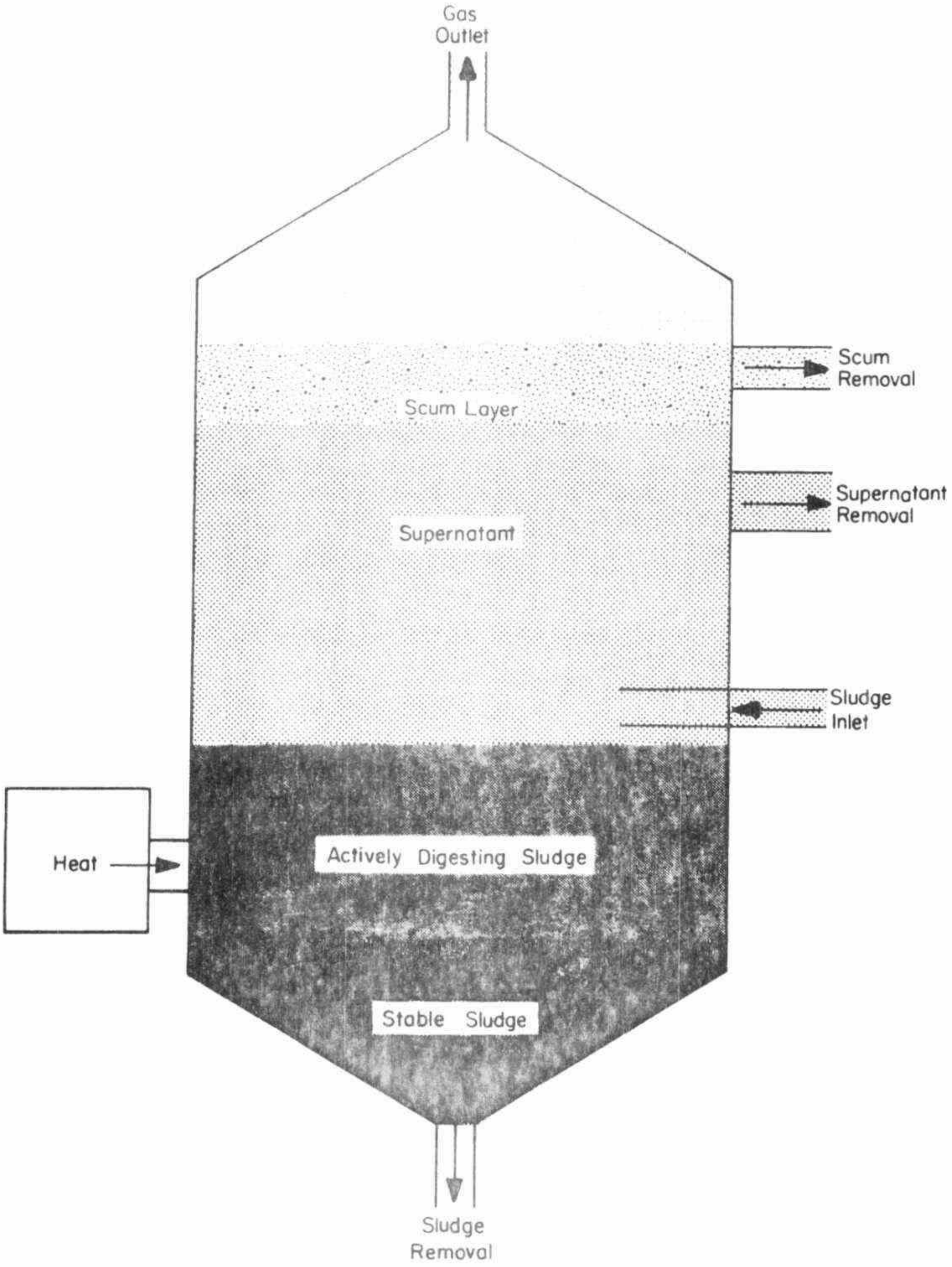


Figure 3-16
Anaerobic Digester

(2) Distribution of the waste at the high point of gently sloping land.

(3) Disposal through ridge and furrow irrigation channels.

Irrigation treatment methods can only be used during warm weather. In Canada, this means approximately 6 - 8 months of the year. Spray irrigation is the most common method in Ontario, finding application in the dairy and vegetable processing industries. Storage facilities are provided for the wastes during the period when spraying is not possible.

A crop cover of grass, clover or other vegetation is usually grown to provide a certain amount of retention and to maintain porosity in the top soil layers. Care must be taken to ensure that direct contamination of the groundwater does not occur - particularly if there are wells in the vicinity.

Table C shows some typical data pertaining to spray irrigation systems.

To avoid clogging of nozzles, large suspended solids should be screened from the wastes prior to discharge. Maintain a pH of about 7 to prevent any harm to the cover crops. A high dissolved solid in the form of inorganic salts can adversely affect the soil.

ION EXCHANGE

Certain synthetic resins have been developed which can exchange ions. By using various resins, undesirable anions and cations can be removed from water or wastewaters. Cations (those with a positive charge) are normally exchanged for hydrogen or sodium ions while anions (those with a negative charge) are exchanged for hydroxyl ions (OH).

Examples of common ion exchanges can be represented by the following equations:

TABLE C

Spray Irrigation of Industrial Wastes

Waste	Application rate USgpm/acre	Average Loading	
		lb BOD_5/ acre/day	lb SS/acre/ day
Tomatoes	100	250 - 300	200 - 250
Corn	150	864	500
Cherries	100	800	654

$$Na_2R + Ca^{++} \rightarrow CaR + 2Na^+$$

AND

$$SO_4 + R(OH)_2 \rightarrow RSO_4 + 2OH$$

(R represents the exchange resin)

Since the reactions are all reversible, it is possible to regenerate the resins and in certain cases, recover the exchanged ion. For example:

$$2Na^+ + CaR \rightarrow Na_2R + Ca^{++}$$

AND

$$RSO_4 + 2OH \rightarrow R(OH)_2 + SO_4$$

Regeneration is accomplished by the use of 5 - 10 percent solutions of brine and sodium hydroxide, respectively.

Ion exchange is accomplished in practice by passing the liquid waste through a bed of resin.

The capacity of the ion exchange material varies with the nature and concentration of the ions in solution and the process is normally economical only if the resins can be regenerated. To ensure contact of the liquid with the resin and to minimize by-passing, the depth of the resin bed is maintained at 24 - 30 inches.

Applied liquid flow rates may range from 2-5 gpm/ft^3. Be careful of breakthrough when operating at the higher flow rates. Breakthrough is defined as the point at which the contaminant appears in the effluent. At this point, the treatment is stopped and the resin bed is backwashed to remove dirt and to regenerate the resin. Continuous operation is maintained by having two or more resin beds and alternating these as required.

Figure 3-17 shows a fixed-bed ion exchanger.

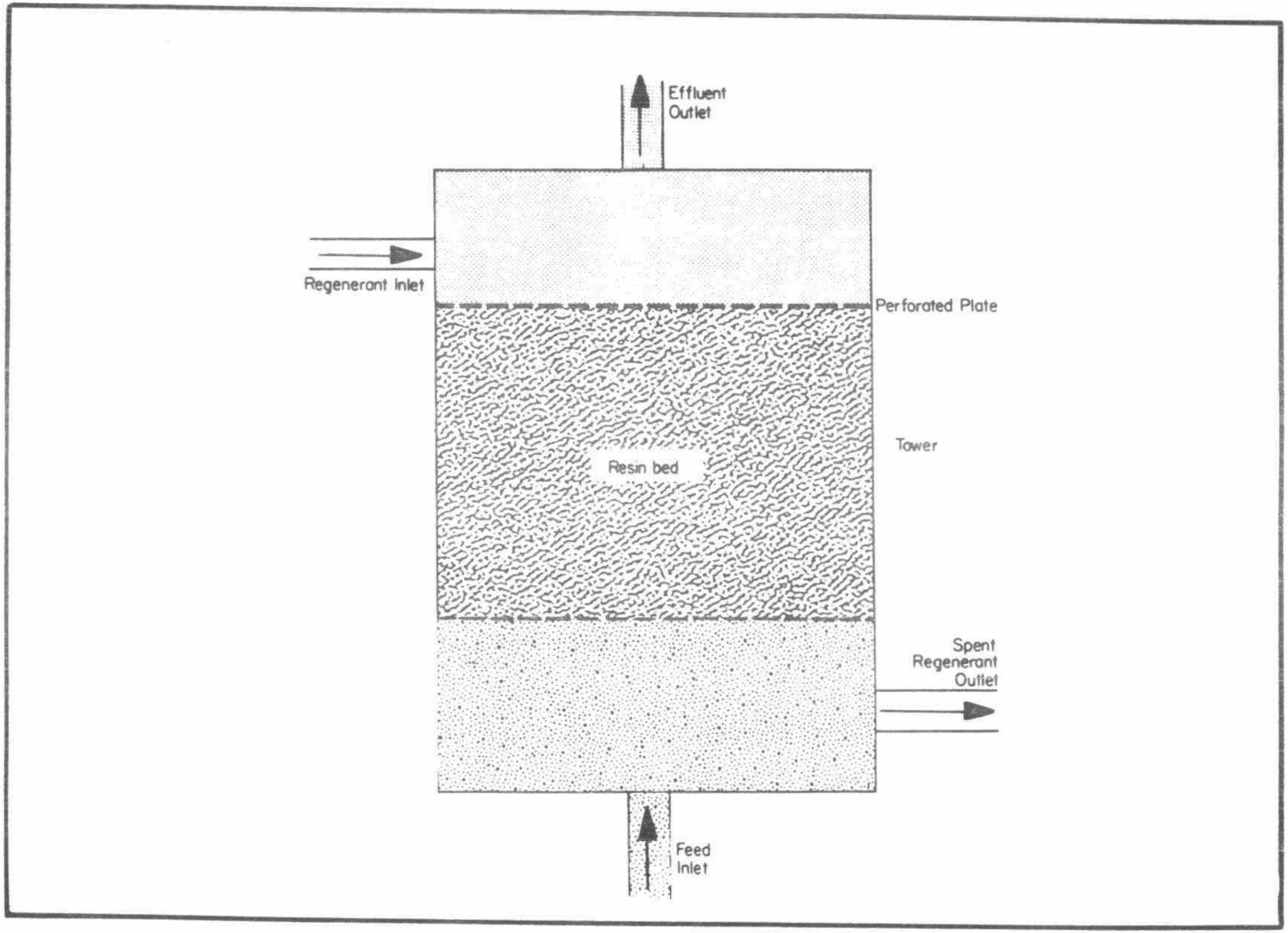


Figure 3-17
Fixed Bed Ion Exchanger

SORPTION

The concentrations of some materials in industrial wastes can be too small to be removed by the conventional biological treatment methods. Examples of such materials are the non-degradable detergents (ABS), some of the cyclic organic compounds benzene derivatives, etc.), cyanides and gases such as chlorine and ammonia. These materials can often be removed by sorption on an "active" surface, such as activated carbon or charcoal.

In practice, continuous carbon filters, with detention times of less than 1 hour, are used, Multiple sorption columns of carbon placed in series is the most economical installation. The first column is saturated when a break-through occurs in the last column of the series. The first column is then replaced with fresh carbon and becomes the last column in the series; the previous last column becomes the second last, and so on.

Materials can be recovered from the carbon by distillation or stream stripping. The carbon is reactivated in the process. Economics will determine whether this step is performed or not.

Carbon filters are finding increasing use as a "polishing" mechanism following more conventional forms of treatment. They are capable of removing some materials which cannot be removed by conventional treatment methods.

REVERSE OSMOSIS

Reverse osmosis is a promising new process having direct application to wastewater treatment. Its major use is in concentrating dilute effluents which cannot be reasonably treated by other means.

To understand reverse osmosis, examine first the principles of osmosis. Osmosis occurs when two solutions of substances at different concentrations, and separated by a "semi-permeable" membrane, try to achieve the same concentration. The solute (water) from the weaker solution passes through the membrane to dilute the stronger solution. This is accomplished by a pressure known as osmotic pressure. The semi-permeable membrane allows the solute to pass through but does not allow the material in solution to pass through.

Figure 3-18 shows this process schematically.

Osmosis stops when a pressure applied to solution A (Figure 3-18) is equal to the osmotic pressure. If the applied pressure to solution A is greater than the osmotic pressure, solute will pass in the reverse direction, that is, from solution A to solution B. This is reverse osmosis.

NOTE: Semi-permeable membranes must be able to withstand the pressures needed to effect a meaningful transfer of solute. The membranes should not plug too readily. Although relatively "clean" water is produced by the process, a concentrated waste is also produced simultaneously and requires treatment and disposal. In some cases, this more concentrated waste is evaporated for by-product recovery or incineration.

Figure 3-19 shows schematically a typical reverse osmosis application. The membrane shown is in tubular form.

Costs and Applications of Reverse Osmosis

Costs of the reverse osmosis system are relatively high at present but the process will find application in many areas where other forms of treatment do not produce the desired clean-up. Possible applications are:

1. The pulp and paper industry for dissolved solids and colour removal;
2. The chemical industry for dissolved solids removal; and
3. The municipal wastewater treatment field.

LIQUID - LIQUID SYSTEMS

There are not many applications of liquid - liquid separation at present in the waste treatment field. One application is the separation of oil and water. Oils continually cause problems in sewers, sewage treatment plants and rivers. Other applications include:

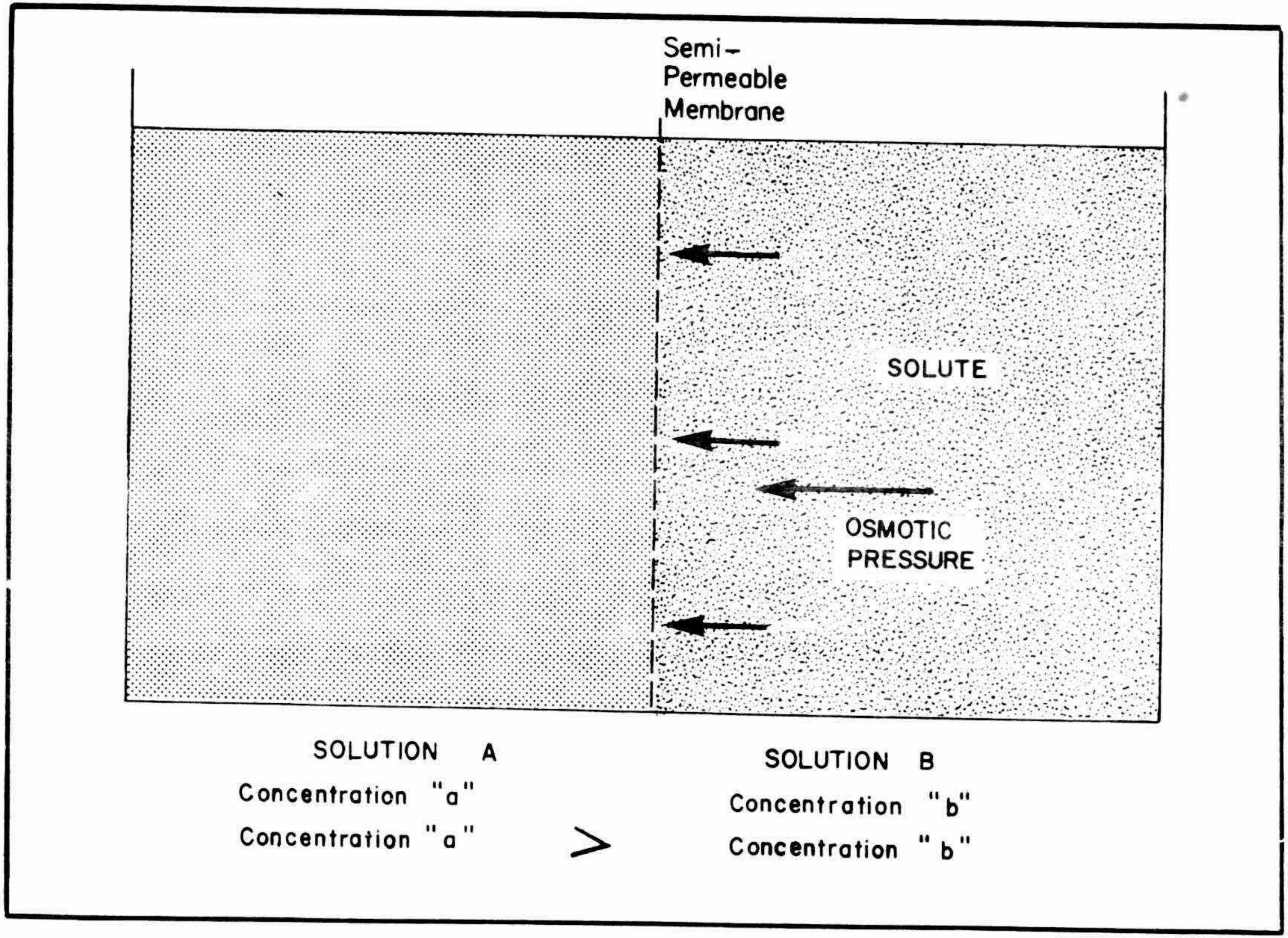


Figure 3-18
Osmosis

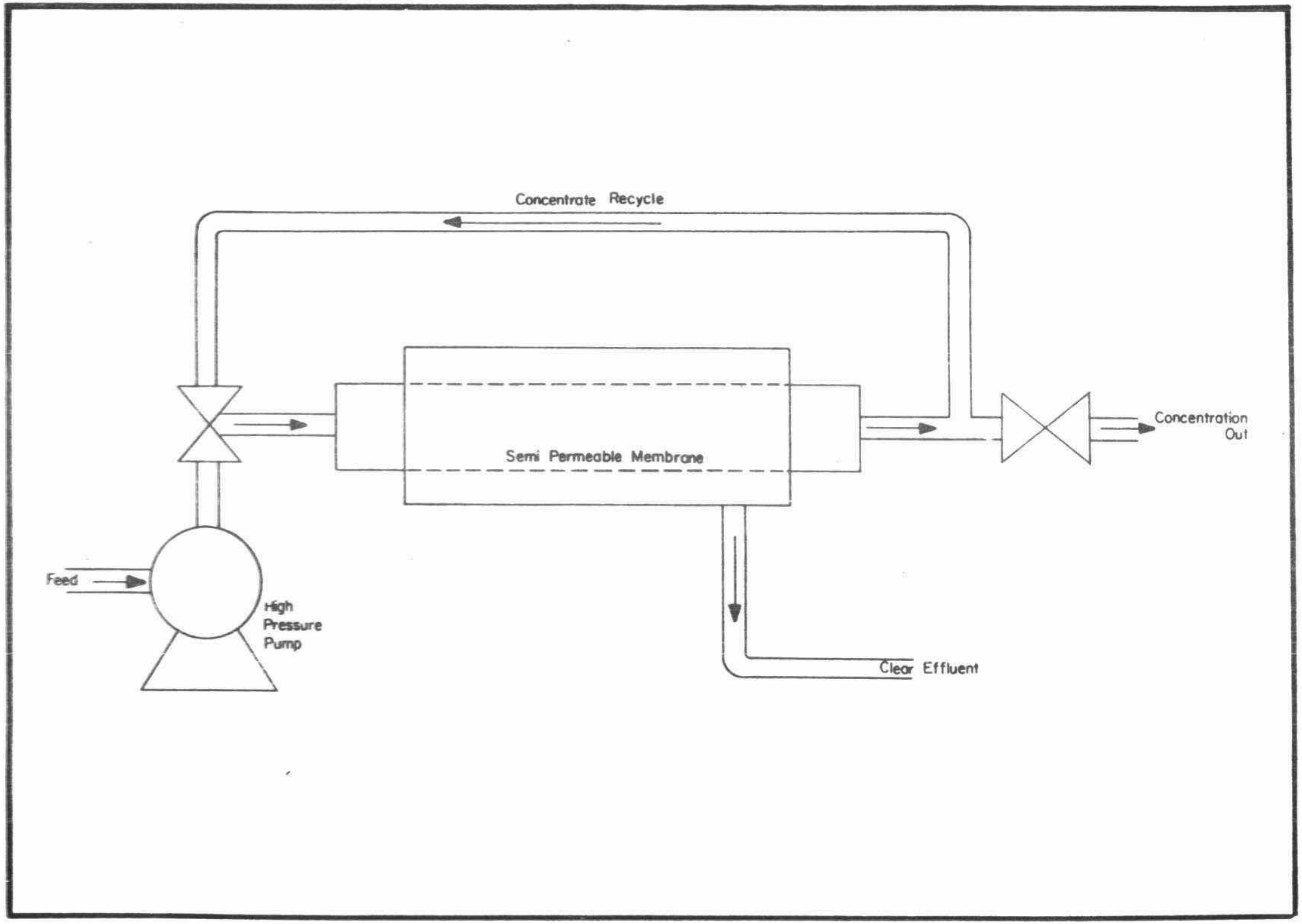


Figure 3-19
Typical reverse osmosis

1. Breaking of emulsions;

2. Separation of greases;

3. Removal of heavier-than-water compounds that tend to collect in the low points of systems.

The simplest way to separate two immiscible liquids is the decanter. In a decanter, sufficient detention time is provided to allow the liquids to separate clearly into two phases: the lighter liquid is on top, the heavier on the bottom. The separated liquids can then be drawn off from top and bottom.

The decanter is normally used where large amounts of both immiscible liquids are mixed. Thus, it has limited application in the waste treatment field.

Figure 3-20 shows a simple decanter.

(1) Emulsion Breaking

When two immiscible liquids are finely dispersed one in the other, the resulting mixture is known as an emulsion. The emulsions most frequently encountered are composed of oil and water; the oil may be dispersed in the water (the usual case) or the water may be dispersed in the oil. If the emulsion is to be stable, a third component called an emulsifying agent, must be present. Soaps, detergents and a variety of naturally occurring substances are good emulsifying agents.

Water-in-oil emulsions are common in the petroleum industry and can be readily broken down by heating which is used in the refinery process.

Oil-in-water emulsions are usually milky white in appearance and are sometimes very stable and difficult to break. To break the emulsion, the emulsifying agent must be inactivated. Inactivation can be accomplished in a variety of ways but economics usually dictate that it be done by pH adjustment or by the addition of coagulants such as

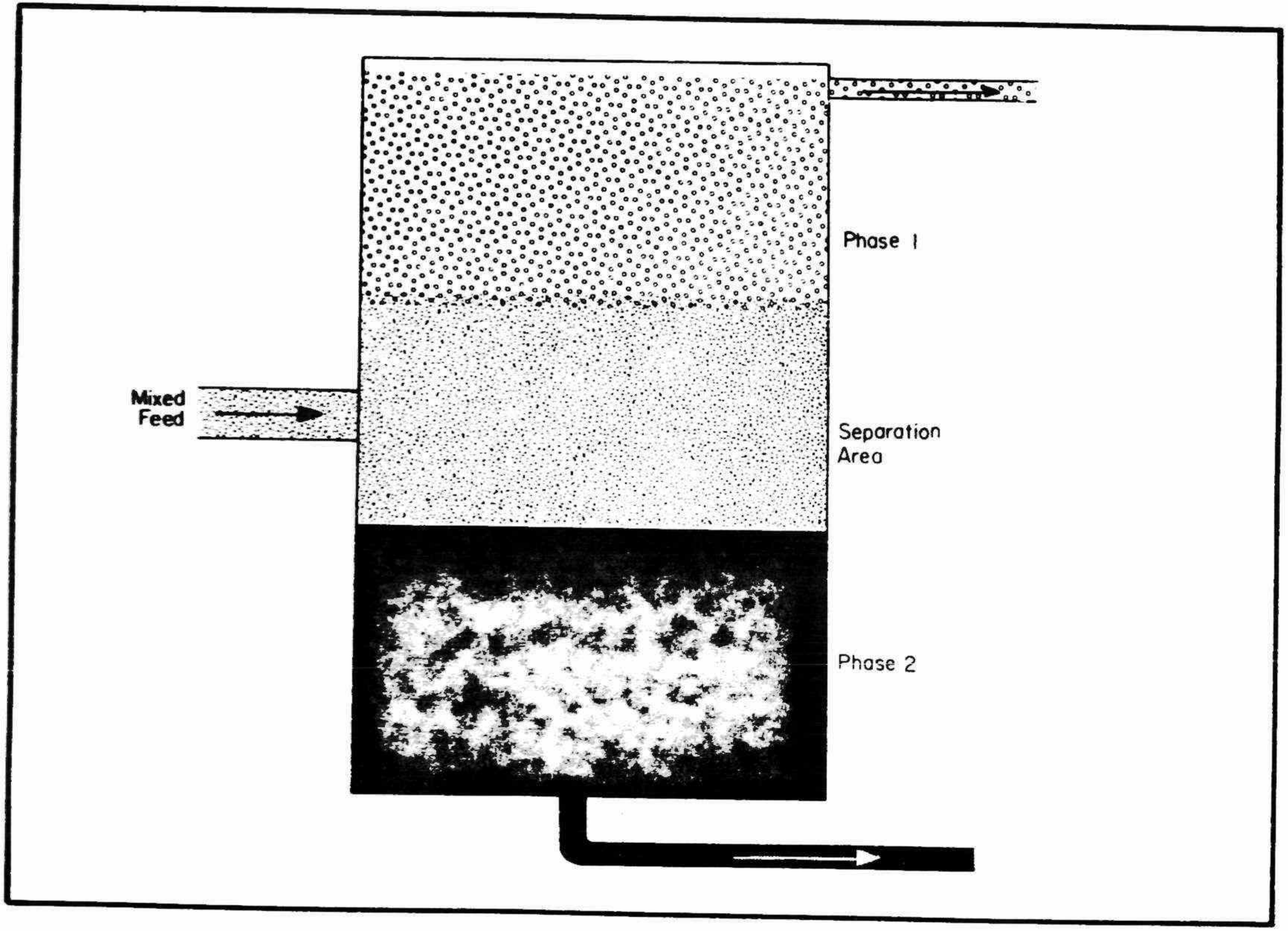


Figure 3-20
Decanter

alum, ferric chloride or lime. The best treatment method must be determined by experiment.

Once the emulsion has been broken, the liquids return to their normal immiscible states and can be separated by conventional means such as decanting.

(2) Oil Separation

Gravity Oil Separator

The density of water is greater than the density of oil. This fact is utilized in the gravity separator. A gravity oil separator operates similarly to a gravity clarifier. The major difference is that the oil floats to the top and is skimmed from the surface in the oil separator whereas the solids settle to the bottom and are removed as sludge from the clarifier.

The American Petroleum Institute (API) has instituted standard designs for oil separators. The designs are based on the recovery of oil for economic reasons rather than pollution control reasons. From the waste treatment standpoint, these separators have not proved too efficient in some instances but improvements are being made continually.

An oil separator provides a stilling zone wherein the oil can float to the surface under quiescent conditions. As a rough guide, the velocity of the moving water is maintained in the range 0.5 - 1.0 feet per second for satisfactory separation.

Figure 3-21 is a schematic of a typical oil separator.

Oil Trap

The oil trap is a smaller version of the oil separator. It is used to prevent the discharge of oil into sewers and storm sewers in areas where oil spills, leakage, etc., may occur. Most gas stations have oil traps installed.

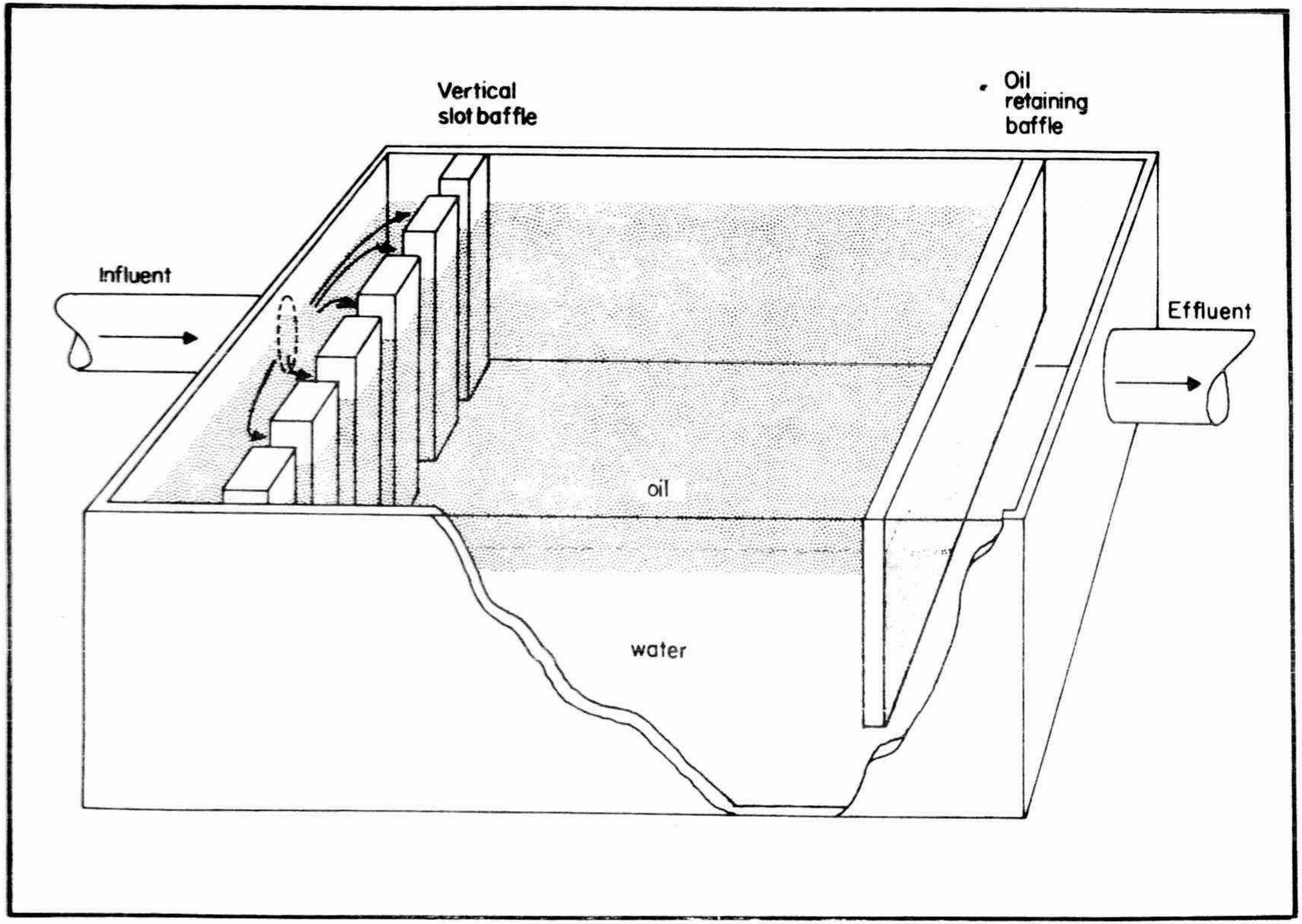


Figure 3-21
Basic Oil Separator

(3) Grease Separation

Greases cause a great deal of trouble when discharged to sewers, storm sewers and sewage treatment plants and every effort should be made to collect them for disposal in some other manner.

A grease trap is similar to an oil separator. It allows the grease to float to the top for removal either mechanically or by hand. Continual or frequent removal of the grease is necessary if the trap is to function properly.

In certain industries such as meat-packing and rendering, the greases are often more difficult to separate. Dissolved air flotation techniques are employed and the floating grease is removed continually.

The flotation system is generally designed for each particular application; however, the principles will be similar to those discussed previously.

(4) Heavier-than-Water Compound Separation

Most liquids of this type to be encountered have significant density differences from that of water and can be separated by gravity. The design of the equipment is similar to that of clarifiers used to remove suspended solids from the wastewater.

(5) Other Liquid - Liquid Separation Systems

Where emulsion breaking and/or gravity separation processes do not provide the degree of removal required, other more costly physical processes are used. These will include stripping, distillation, absorption and evaporation. Another method to consider is activated carbon adsorption.

GAS - LIQUID SYSTEMS

Gas - Liquid Systems are rare, the most common being foam. Foams consist of dispersions of gases in liquids which create an aesthetic nuisance. Foams, like emulsions, need the presence of a stabilizing agent if they are to persist for any length of time. Soaps and detergents can create stable foams. Since the advent of biodegradable detergents, the foaming problems encountered as a result of detergent usage have decreased but many industrial wastes, including those from the pulp and paper, textile and meat packing industries can generate severe foaming problems.

The two main methods used to destroy foams are:

1. The use of water sprays to break up the foam by mechanical action and dilution;

2. The use of anti-foaming compounds.

Water sprays often provide only a temporary solution to a problem unless sufficient dilution water is added to render the foaming agents inactive. Anti-foaming agents are sometimes poisonous, affecting the operation of a treatment process or harming the aquatic life in a stream. Most anti-foaming agents tend to be relatively inert, however, and can be used for most applications.

Not too often, other gas - liquid systems involve situations where a gas is in solution in the wastewaters and needs to be removed. Generally, stripping or distillation must be used to remove the offending gas. For example, ammonia present in relatively high concentrations can be stripped from solution by boiling or by air stripping.

DISPOSAL OF CONCENTRATED WASTES

Many of the pretreatment and treatment processes described previously produce a secondary concentrated waste. Also, many concentrated wastes which cannot be treated by methods previously outlined are produced by industrial processes. All of these concentrated wastes must either be subjected to further treatment or disposed of in a satisfactory manner.

A waste is defined as any material which the owner considers will cost him more to keep than to discard. At some stage in the design of a plant, a decision is made as to whether the waste should receive further treatment or be discarded and the following factors must be considered:

(1) *What alternatives are available? If the waste can be dumped into the nearest ditch with impunity, there is little incentive to spend money on further treatment.*

(2) *The operator's point of view: should further inplant treatment be given and the surplus waste hauled away for disposal?*

Cost may not necessarily be purely financial. It may comprise: (a) a penalty in terms of time and effort, (b) a nuisance, or (c) a hazard, including health hazards.

In the past, consideration of the cost to the community or the environment of discarding waste was not taken into consideration; to be quite fair, it was rarely considered even by the designers of treatment plants. An obvious example is municipal sewage, where until recently multimillion dollar plants were designed for treatment, but little provision was made for the disposal of sludge.

TYPES OF CONCENTRATED WASTES

The major categories of these wastes include:

(1) *paint sludges*
(2) *resin sludges*
(3) *solvents*
(4) *water-oil mixtures, emulsions and sludges*
(5) *acid wastes*
(6) *alkaline wastes*
(7) *plating wastes*
(8) *neutral salts*
(9) *organic wastes*

A separate category might be made for soluble salts - e.g. spent brine solutions.

The quantities involved are extremely difficult to determine accurately, even after detailed market surveys.

Being liquid, these wastes pose a number of specific problems in handling, treatment and disposal. Major industrial plants will often install treatment facilities to dispose of their own wastes. However, in many instances concentrated wastes cannot be dealt with in this way for the following reasons:

(1) Lack of technology regarding treatment. An example is brine.

(2) Unless large quantities of one particular waste are being produced, the cost of in-plant treatment may be prohibitive.

No matter how well planned and well operated a facility may be, breakdowns do occur which frequently involve the need for prompt disposal of large quantities of untreated waste.

Waste Disposal Sites

"Disposal Sites" include treatment facilities as well as the ultimate disposal operations and also include intermediate transfer facilities if these are provided.

Waste Management System

A Waste Management System includes the complete system of storage, collection, transportation, treatment and disposal of waste. The individual elements of the system are usually intimately interlinked and cannot be dealt with in isolation. However, for this particular discussion, "System" can be assumed to mean the handling and transportation of the waste only.

Certificate of Approval

All operators, either of sites or of systems, must obtain a Certificate of Approval from the Waste Management Branch. A Certificate of Approval is issued for any period up to one year, when it must be renewed, and may be conditional upon the implementation of a program of improvement.

Collection and Transportation

Dealing first with the collection and transportation system, a major problem results from the fact that the individuals and firms hauling the waste are essentially intermediaries between the producer and the disposer. Frequently, the smaller industries have no storage facilities to provide a full tank-truck load, with the result that one tank-truck might pick up wastes from a number of different industries in one trip. This has obvious hazards, and limits the feasible methods of disposal treatment which is compounded by ignorance of the problems involved by the majority of haulers, and indeed by some of the industries.

This is particularly significant in the control of operations at a large central treatment plant for these wastes. It may well be necessary to require, by regulation, the issue of some form of bill of lading by the producer of the waste to the hauler, who would, in turn, provide a copy to the disposal site operator. This also implies the development of a classification system for wastes to provide information adequate to determine the treatment required, the degree of any hazard involved, and any special measures which must be taken either in transportation, treatment or disposal.

Treatment and Disposal

Turning now to treatment and disposal, there are a limited number of general solutions:

(1) *Disposal onto land;*
(2) *Disposal into land (into deep wells, caverns or mines);*
(3) *Surface storage (lagooning),*
(4) *Permanent storage (by burial or in vaults);*
(5) *Physico-chemical treatment;*
(6) *Thermal treatment.*

(1) *Disposal onto Land*

In general, the types and quantities of liquid waste which can be disposed of in this way are limited.

Spray irrigation or ridge and furrow disposal are feasible for some organic waste. Pretreatment by oxidation or anaerobic digestion is desirable to limit odours and is necessary if, as in the case of sewage sludge, the waste is to be used on farm land as a soil conditioner.

Large quantities of oil are utilized on roads for dust control in the summer months. This is an acceptable practice when the necessary controls to prevent runoff are applied.

Limited quantities of a variety of liquid wastes can be disposed of on suitable solid waste disposal sites, though serious operational problems may result unless very carefully controlled. Sanitary landfills are normally deliberately designed to reduce the quantity of liquid which will percolate through the waste, limiting the problems involved in leachate entering subsurface aquifers. An exception might be the use of a completed municipal waste disposal site with a substantial depth of waste and under-drainage which will collect leachate for treatment.

With this exception (to be discussed later), and re-use of processed organic waste as a soil conditioner, the disposal of industrial wastes onto land is an undesirable expedient with the potentiality at least for abuse and should be phased out at the earliest opportunity. There are two problems related to the disposal of organic wastes onto land which should be mentioned. Organics are oxidized in the soil to nitrogen compounds. High levels of nitrogen compounds in well water supplies may have direct public health implications. For this reason, controls over the disposal of sewage sludge on agricultural lands must limit the application in relation to the nitrogen uptake of the crops grown. Also, repeated applications of certain wastes may result in the concentration of heavy metals. This certainly warrants further investigation.

An inter-departmental committee has recently completed the preparation of interim guidelines for the use of processed organic waste as a soil conditioner and these will shortly be incorporated as regulations under the Environmental Protection Act.

(2) Disposal into Land

At present in Ontario, this is confined to deep well disposal.

Some use may be made in the future of disused mines. In fact, this was given very serious consideration when large quantities of D.D.T. had to be disposed of following the Provincial ban, as was the possibility of burial in mine tailings areas.

Deep well disposal into suitable underground formations is an acceptable method for some wastes. However, suitable underground formations are limited both in geographical extent, and in their capacity to receive waste. In fact, they represent a resource which should be conserved by requiring surface treatment of all practicable wastes.

The formation now being utilized for this purpose in Ontario is the Detroit River sands in the Sarnia area which is between 600' and 900' deep. The only significant problem which has resulted from the use of these wells has been the large number of improperly plugged wells into the same formation in certain areas, particularly along the St. Clair River Valley. For this reason, it is proposed that all injection of waste by pressure into this formation cease. The industrial wells used in the past have been closed down over the past two years as treatment plants were installed.

Certain wells into this formation make use of what are termed "lost circulation zones" which do not require pressure injection, and consequently offer little danger of pollution to other aquifers. These particular wells will be permitted to continue accepting all types of wastes until the end of 1973 and subsequently will be permitted to accept brine.

Only one well has been drilled for waste disposal into the Cambrian formation which is at a much greater depth, and consequently has even more limited risks. However, there is no way of estimating the volume of waste that any particular well will take, if any, and the cost and risk of development of this formation has prevented its exploitation up to the present.

Recently, amendments to the Environmental Protection Act provided Legislative authority to the Waste Management Branch to control this method of disposal. In practice, the control will be exercised by an inter-departmental committee with representation from the Waste Management Branch, the Industrial Wastes Branch and the Water Resources Branch of the Ministry of the Enviornment, and the Petroleum

Resources Branch of the Ministry of Natural Resources.

In addition, the amendment provided authority to require all disposal well operators to contribute, on the basis of quantity and type of waste injected, to a fund which will be used to provide alternative water supplies should any be made unusable due to deep well disposal operations.

(3) Surface Storage

This is essentially a transfer station operation, where wastes are stored temporarily until they can be disposed of.

Evaporation, in the climate of Ontario, is of no significance, and in ground conditions where seepage takes place, there is danger of ground water contamination.

Storage lagoons for sewage sludge are used extensively during the winter months when weather conditions make it undesirable or impracticable to spread the waste on land.

Greater use might be made of lagoons for a number of organic wastes by the use of aeration, possibly only to the degree which would prevent odours during storage and subsequent disposal.

(4) Permanent Storage

This method is particularly applicable to hazardous wastes which require special precautions in handling or disposal, and for which treatment is impracticable.

Highly radioactive material is an example, but the same practices are being followed for mercury, certain wastes from the petro-chemical industry and pharmaceutical wastes from laboratories and institutions. A comparatively small quantity of a very wide variety of materials, some of which may be extremely toxic, are involved in this case.

The specific method of disposal varies considerably. In principle, the wastes are stored to prevent the passage of water through them. Usually burial takes place at comparatively shallow depths above the maximum water table, preferably in clay soil. The trenches used may be additionally sealed with plastic or other liner and the wastes covered with earth, shaped, and again sealed with plastic. Frequently the wastes are packed in drums, and occasionally by the double drum method, the annular space between the two drums being filled with concrete.

The Federal Government has recently proposed the construction of specially designed storage vaults for radioactive material.

(5) Physico-Chemical Treatment

The processes used are very similar to those utilized for in-plant treatment. They include neutralization and precipitation, the discharge of an acceptable effluent to a receiving body of water or perhaps the concentration of the effluent for deep well disposal, permanent storage or thermal treatment, and frequently also result in a concentrated sludge which may require further treatment before disposal.

One recent development should be mentioned under this heading; the addition of chemicals to a waste with the object of solidifying it, so that it can be utilized for landfill. It is claimed that in many instances a non-leaching solid is formed and the hardening process is controllable within limits, so that, for example, waste could be pumped from storage, the appropriate chemicals added and the treated waste subsequently pumped to the point of disposal where the reaction would take place. Limited information is available on the comparative economics of this method of disposal, but it appears that the more concentrated the waste, the more economical the process.

(6) Thermal Treatment

The most appropriate method of treating waste materials containing hydrocarbons or similar combustible components is by incineration. If the waste contains contaminants which may result in air pollution, sophisticated scrubber systems are necessary. In turn, they will produce wastewater requiring treatment and disposal.

A fluid bed reactor offers the possibility of disposal not only of combustibles but also of many sludges and concentrated wastes from other treatment processes; it also offers the possibility of reclamation of some of these materials. All the various methods described may be used for specific problems in specific areas. However, if there is a concentration of industry, the best solution is the establishment of a central treatment facility. Such a facility can provide the pollution control equipment necessary which would be exorbitantly expensive if provided by each individual industry producing waste. Moreover, in many instances, one waste can be used to assist in the treatment of another, again reducing costs.

Receiving and Storage Facilities are Critical

While such plants may vary substantially in the treatment processes used, they have a number of aspects in common. The design and operation of the receiving and storage facilities are critical. For example, drum handling facilities should allow the contents to be unloaded into receiving tanks. Transfer from the receiving tanks to the tank storage farm or the treatment facilities must not take place until the waste has been analyzed to determine the storage and treatment required. (An exception to this might be wastes hauled by the plant operator. Usually the wastes have been analysed beforehand and the necessary controls have been developed and used to ensure the delivery of uniform material in the wastes.)

An integral part of the receiving and storage facilities must be a well equipped laboratory. Here the necessary analysis of the wastes can be performed as a safety precaution and to determine the detailed treatment processes required.

Due to the very large variety of wastes handled at such a plant, the processes may be complex. In addition to those earlier mentioned, inorganic salt solutions may be concentrated by evaporation, sludges may be dewatered by filtration, and humus filters may be used as a means of dealing with certain difficult organic wastes.

Generally, each particular waste material is analysed and treated with the appropriate reagents in successive steps. In many cases, this treatment will not be the final step. A clarified liquor and a sludge are produced which may require further treatment or disposal at the site or at another more suitable site.

CHAPTER IV

FLOW MEASUREMENT

INTRODUCTION

The measurement of the volume of liquid effluents being discharged by an industrial complex is another vitally important aspect of any industrial plant survey. Discharges to municipal sewer systems require knowledge of the volume of discharge to allow calculations of suspended solids loadings, BOD_5*, etc. These loadings are required for sewer system design, surcharge calculations and by-law enforcement. In addition, a company can benefit from learning the magnitude of its process losses because minor changes can produce savings in operating costs.*

It is often necessary in an industrial establishment to obtain a water balance and process material balance to determine the efficiency of a particular process unit or waste treatment facility. Such balances are only possible with accurate flow measurement.

In cases where discharges are made to natural watercourses, the volume and loadings of waste components must be studied to evaluate resulting stream conditions and to determine whether the requirements of pollution control agencies are being met.

GENERAL

In an industrial plant, liquid wastes are conveyed to a sewer or discharged from the building in one of two ways:

(a) closed conduit or pipe
(b) open channel or ditch

Generally, different types of measuring devices are required to measure the flow in the two cases, although some devices are applicable to both. Both the closed conduit and the open channel will be encountered in industrial plants, so a knowledge of the types of measuring device most frequently used will help. The majority of flow measuring devices require permanent installation, but some are *portable and can be used to great advantage during a plant survey (particularly as a check against installed equipment).*

FLOW MEASUREMENT IN CLOSED CONDUITS OR PIPES

(1) Bucket - Stop Watch

This time-honoured method is still used extensively. It is one of the most convenient methods of measuring flow, provided the open end of the pipe is accessible, and a bucket can be conveniently placed under the open end to catch the discharging liquid. The bucket, or container, should be big enough to take at least 30-60 seconds to fill. A larger container requiring more time to fill should be used if greater accuracy is needed. The flow is measured three or four times and the results averaged for greater reliability. This method is particularly useful for smaller effluent volumes and for calibrating other flow measuring devices.

(2) Open-End Pipe Discharge

The distance which water jets out from an open-end horizontal pipe depends on the flow of water in the pipe. A system of measurements can be established (figure 4-1) and the following equation can be used:

$$Q = \frac{1500\ A.X.}{Y^{1/2}}$$

where

Q = flow in imperial gallons per minute (Igpm).

A = cross sectional area of liquid in the pipe.

X = the distance between the end of the pipe and the verticle axis measured in feet (measurement is made parallel to the pipe).

Y = vertical distance in feet from the surface of the water at the discharge from the pipe to the intersection of the water surface with the vertical axis.

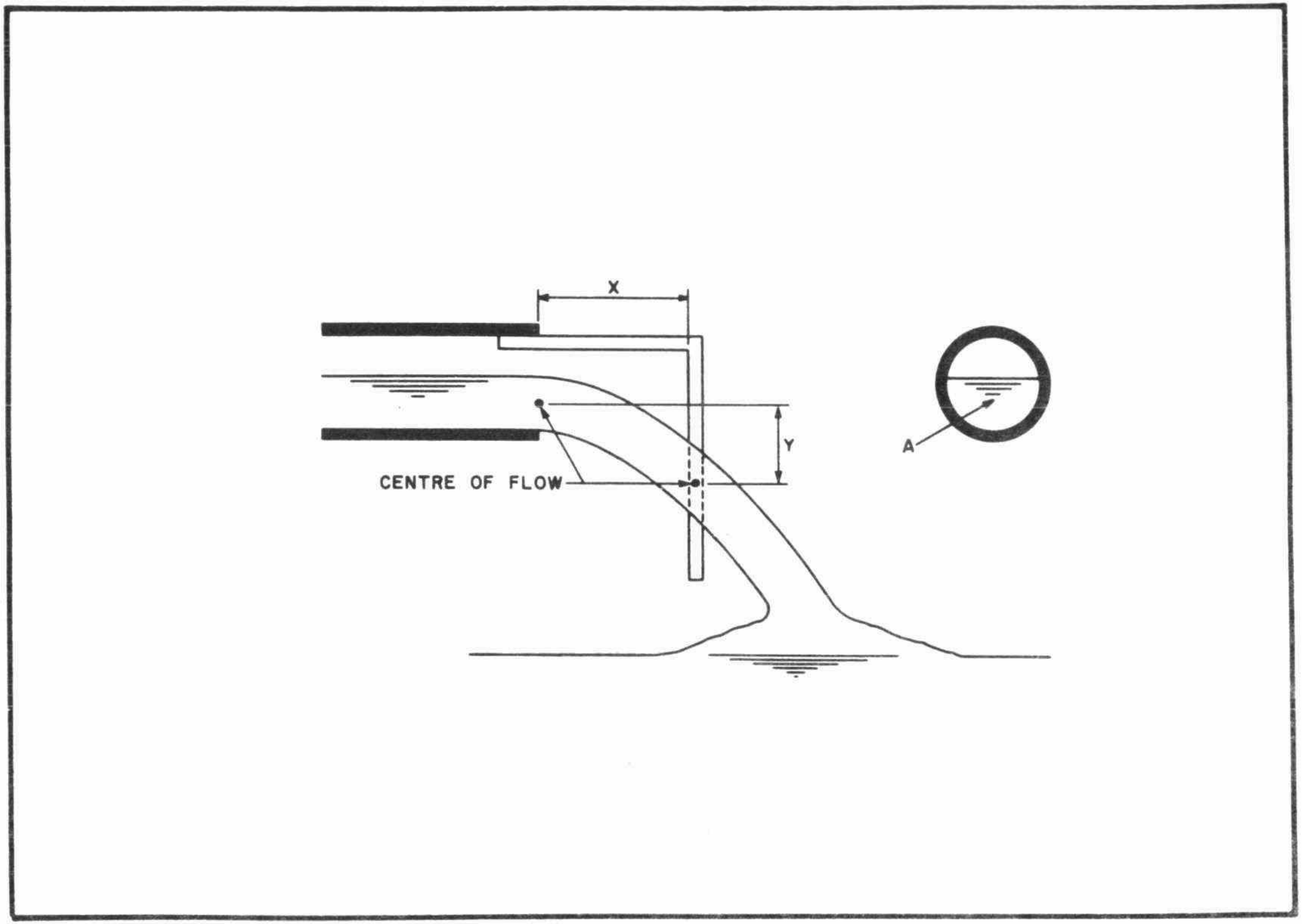


Figure 4-1
Open End Pipe Discharge

In practice, the actual flow pattern will rarely be as clean-cut as in Figure 4-1 so some judgement will be required, especially in the measurement of "Y".

This method of estimating the flow only applies where the pipe does not run full. A similar method can be developed for pipes running full, but the formula is more complicated and outside the scope of this presentation.

(3) Velocity Measurement

The flow in certain pipes having relatively long straight runs may be estimated by measuring the velocity and using the formula:

$$Q = 9.64\ V \times A$$

where Q = flow (Igpm)

V = velocity of liquid in pipe (ft./sec.)

A = cross sectional area of pipe (sq. ft.)

To measure the velocity, time the passage of a suitable indicator such as a piece of wood, a rubber ball, an orange, etc., through a measured length of the pipe.

(4) Standpipe Overflow Weir

This method of estimating the flow is also shown as the California Pipe Method and is shown in Figure 4-2. The pipe must be perfectly horizontal so that depth of water in the pipe becomes a function of the flow through the pipe. The following formula can be developed to describe the relationship between flow and pipe:

$$Q = 3250\ (1-\frac{A}{d})^{1.88} d^{2.48}$$

where Q = flow (Igpm)

d = pipe diameter in feet

A = vertical distance in feet between the upper inside surface of the pipe and the surface of the liquid.

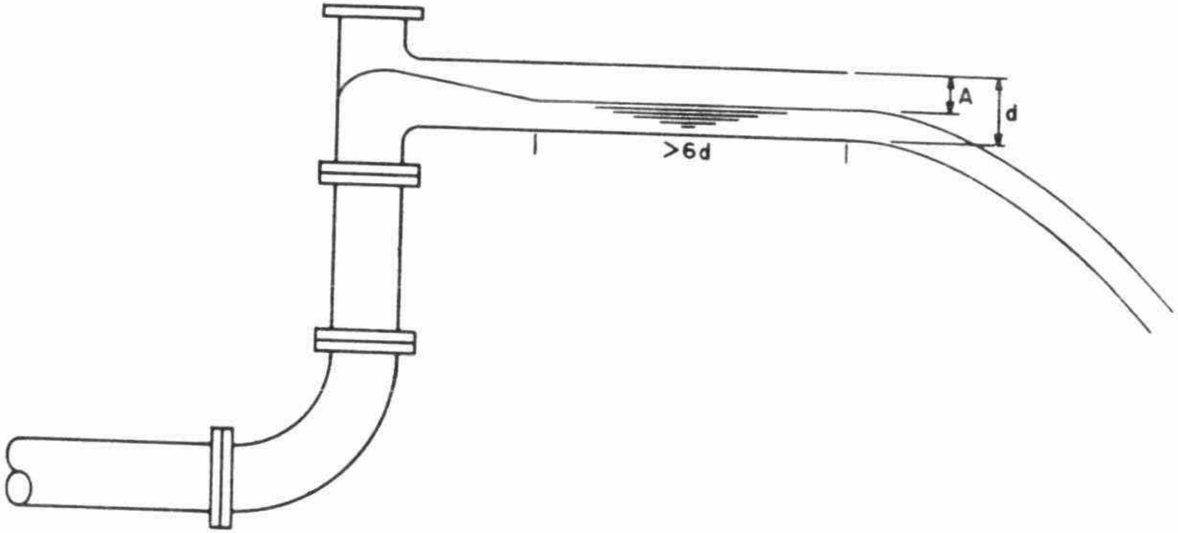


Figure 4-2
Standpipe Overflow Weir

(5) Dilution Method of Flow Measurement

Where sewers are inaccessible or the installation of a flow measuring device is not feasible, the dilution method of flow measurement is recommended. Add a known concentration of material into the sewer at a constant rate and then sample the mixture at a point downstream in the sewer where adequate mixing has occurred. Collect a sample upstream from the point of addition to determine background levels and have all samples analyzed for the added material.

Any material that is stable, non-reactive with the wastes in the sewer and easily analyzed may be used. Sodium chloride (common salt) is commonly used because sodium analyses are readily performed using flame photometry. Fluorescent dyes (fluorescein) may also be used because concentrations can be readily measured by the use of fluorometry.

The flow in the pipe may be calculated as follows:

$$Q = \frac{g \times C_o}{C_2 - C_1}$$

where Q = flow rate in (Igpm)

C_o = concentration of material added (mg/l or ppm)

g = metered flow of material added (Igpm)

C_2 = concentration of material at downstream location (mg. l or ppm)

C_1 = concentration of material at upstream location (mg. l or ppm).

The most difficult part of this method is maintaining constant feed rate of added solution. For a true constant feed rate, a constant head device is required either to feed by gravity or to provide a constant head for the suction of a small metering pump. The device shown in Figure 4-3 is recommended as a convenient method of providing a near constant head.

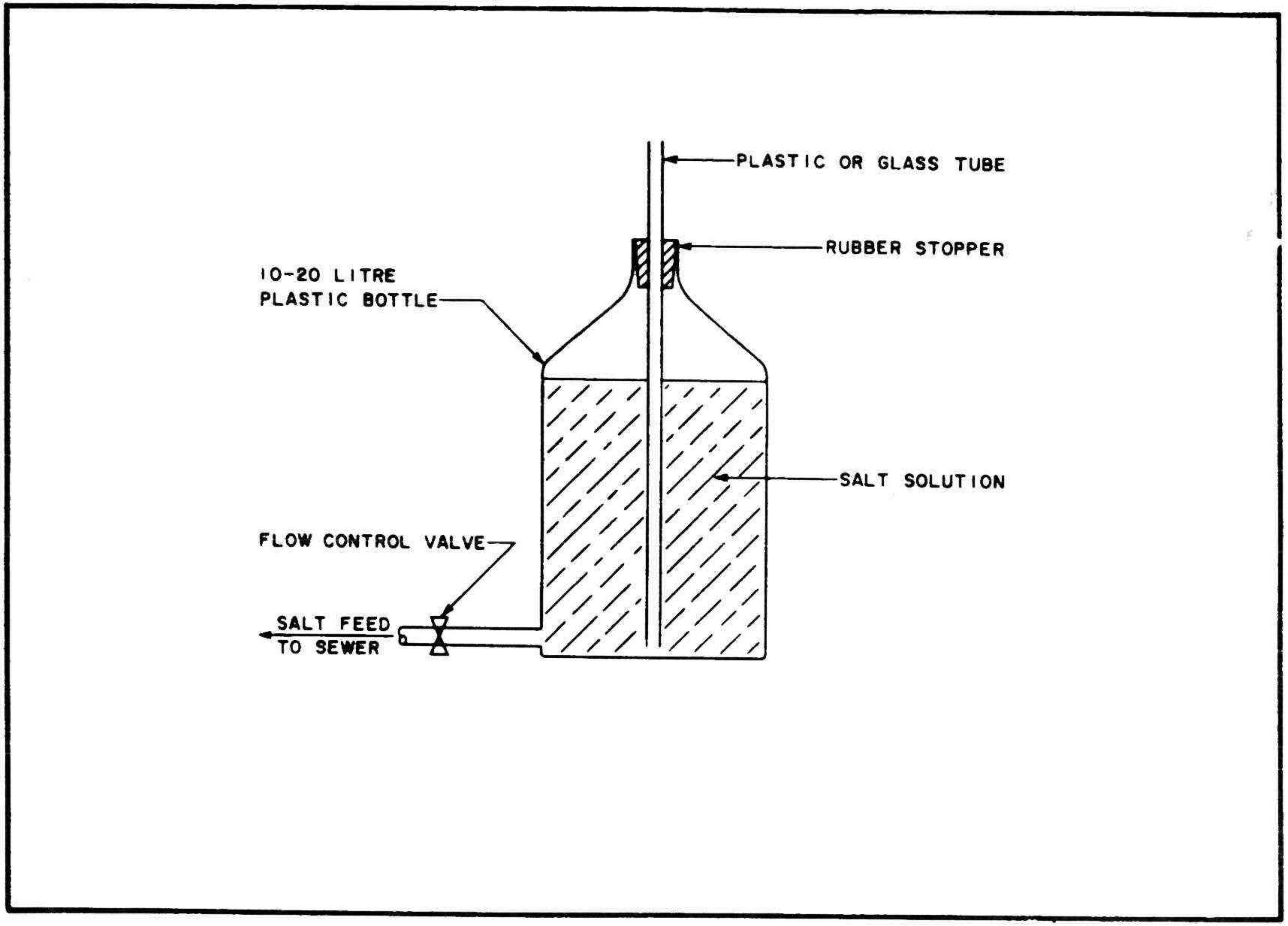


Figure 4-3
Constant Feed Device

(6) Velocity Measurement Using a Pitot Tube

The pitot tube (Figure 4-4) may be used for estimating the flow in a closed conduit or pipe, but its use necessitates the drilling of a small hole in the pipe to allow the tube to be inserted.

The most convenient type of pitot tube consists of a double concentric tube with the centre tube open at one end. At a distance of 8 diameters from the open end, a number of small holes are drilled through the outer tube. Other pertinent dimensions are shown in the Figure.

In operation, the pitot tube is inserted into the closed pipe. The open end of the tube faces into the flow and the two other ends of the tube are connected to a manometer and the pressure difference is read.

As the velocity of flow varies across the section of a pipe, it is necessary to measure the velocity at a number of points across the pipe. Guidelines are available to indicate the locations where the velocity should be measured.

The mean velocity of flow in the pipe is then determined by averaging the velocities measured at each point on the traverse. If the cross sectional area of the pipe is known, the flow may be computed from:

$$Q = V_a \times A \times 9.64$$

where V_a is the mean velocity of flow

A = cross sectional area of the pipe (sq. ft.)

Q = flow in Igpm

The pitot tube should not be used at low liquid velocities and where suspended solids are present.

(7) Flow Measurement by Head Loss

Liquid flows in a pipe at a given velocity and pressure. If a constriction is placed in the pipe or conduit carry-

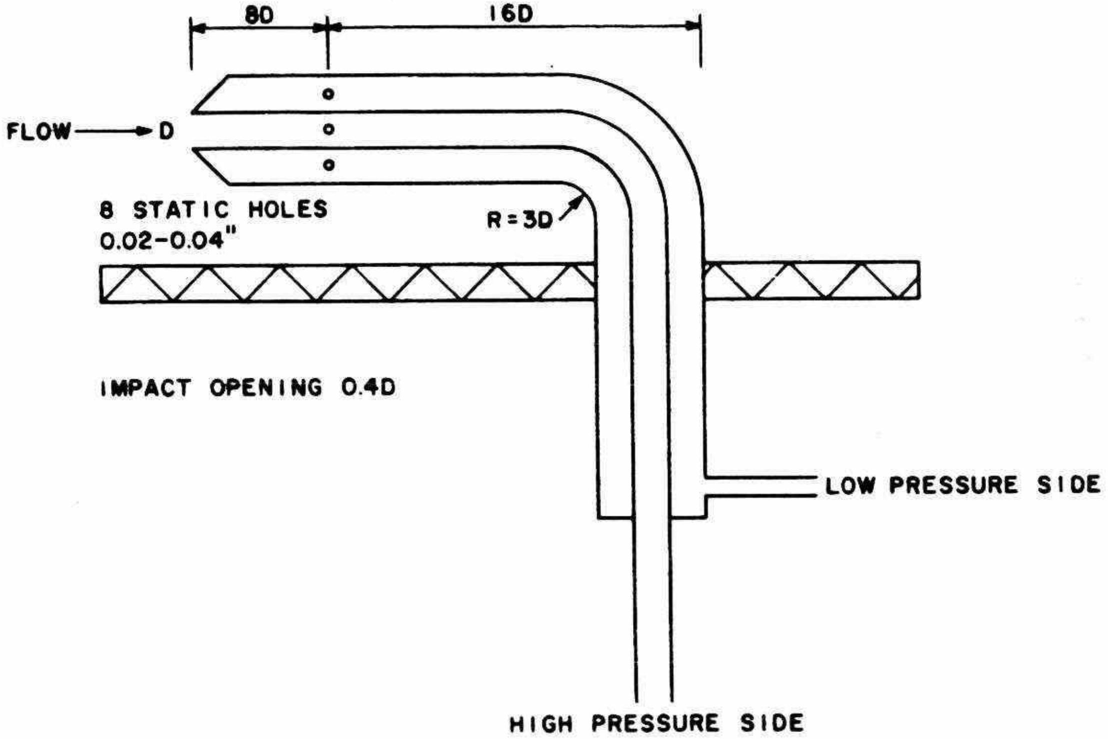


Figure 4-4
Pitot Tube

ing the liquid, there will be an increase in the velocity of the liquid as it flows by the constriction, and a corresponding reduction in pressure. The rate of flow through the constriction can be calculated if the reduction or loss of pressure (Δh), area (A) for flow through the constriction, the density of the fluid, and the coefficient of discharge (C), are known. (C) is defined as the ratio of actual flow to theoretical flow and makes allowances for stream contraction and for effects due to friction. The rate of flow is calculated using the following formula:

$$Q = 9.64\ C \times A \times 2g \times \Delta h$$

where g = acceleration due to gravity (ft./sec./sec.)

Δh = pressure loss in feet of fluid

A = cross sectional area at constriction (sq. ft.)

Q = flow (Igpm)

C = coefficient of discharge

If any difference in elevation occurs because of the inclination of the pipe, a modified formula is required.

A number of devices have been developed which operate on this principle, such as:

(a) Orifice Meter

The orifice meter consists of a sharp-edged orifice plate placed in the pipe to form a restriction. Pressure tappings are made upstream and downstream of the orifice plate (or orifice) with the distance of the tapping from the orifice depending on the type of tapping. Figure 4-5 shows the 'radius tapping' where the upstream hole is located 1 pipe diameter from the orifice and the downstream hole 1/2 pipe diameter from the orifice.

(b) Venturi Tube Meter

Greater accuracy in flow measurement can be obtained if a more gradual approach to and discharge from the constric-

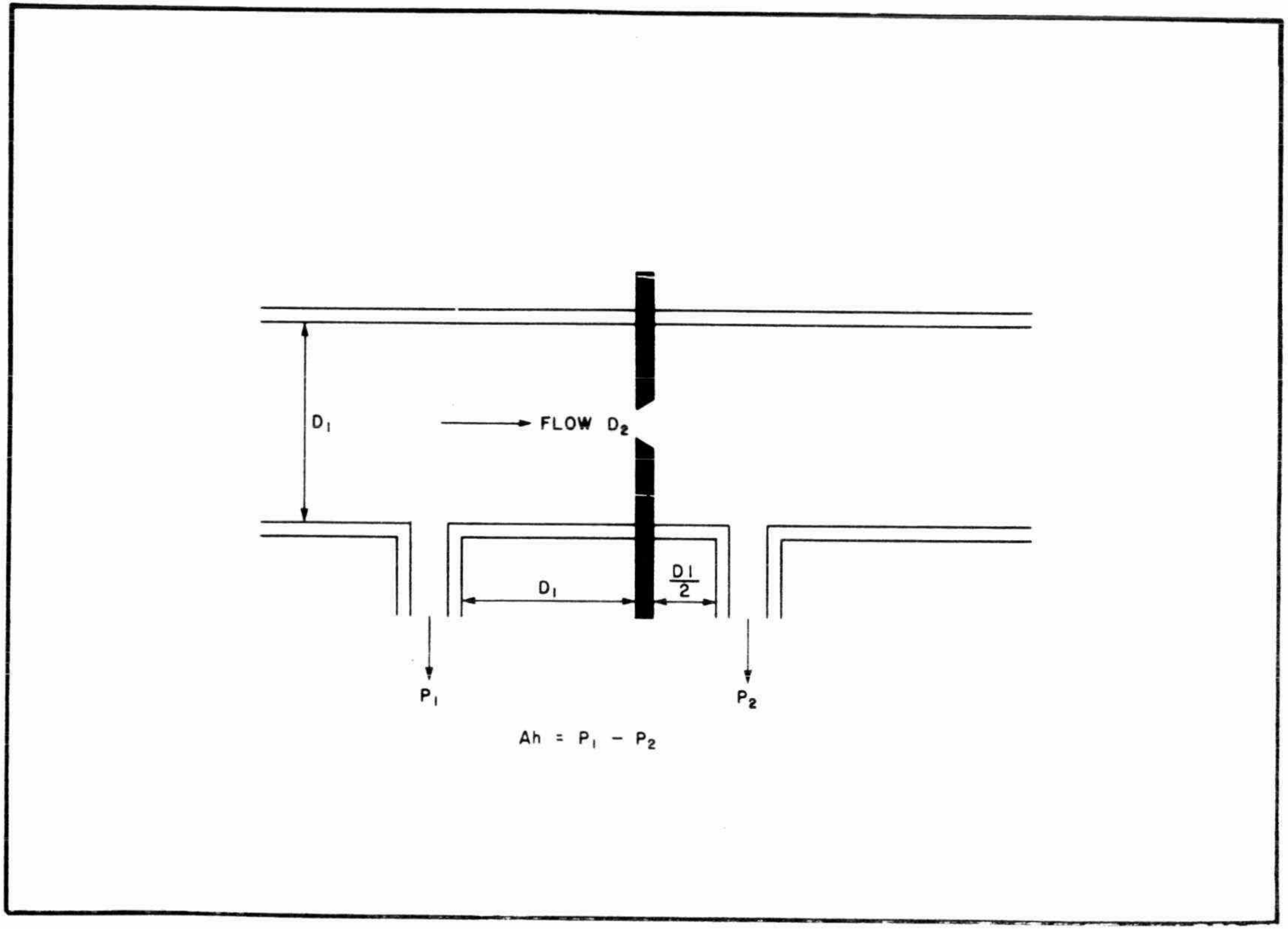


Figure 4-5
Orifice Meter

tion are made. Less turbulence and less permanent head loss are created. This is the principle of the Venturi-tube meter. (Figure 4-6).

The angles for the cones of approach and discharge are specified at 21 ± 2 degrees and 5 to 15 degrees respectively, and the constriction or throat length is equal to one throat diameter.

If the meter is installed in the horizontal position, use the equation given for the orifice meter. If the meter is inclined, a correction term must be included.

(c) Miscellaneous Head-Loss Meters

A number of variations on the orifice and venturi are available that claim to give greater accuracy, longer life, self-cleaning features, etc. Orifices may be segmented or eccentric, particularly for applications where solids might build up behind a concentric orifice and affect the flow pattern.

A 90^o elbow may be used as a flow measuring device if the differential centrifugal head between the inner and outer radii of the bend is measured by means of taps located midway around the bend. However, this measuring device requires calibration since determination of the discharge coefficient ("C") from theoretical concepts is not practical.

Square edged orifices and venturi tubes have been so extensively studied and standardized that accuracy within 1 and 2 percent can be assumed when the meter is new and clean. Therefore, with correct pressure measurement and proper selection of the discharge coefficient "C" from the literature, this order of accuracy can be expected.

Corrosion and plugging are the problems most often encountered in industrial applications. Square edged orifices should not be used with abrasive liquids that could damage the edge.

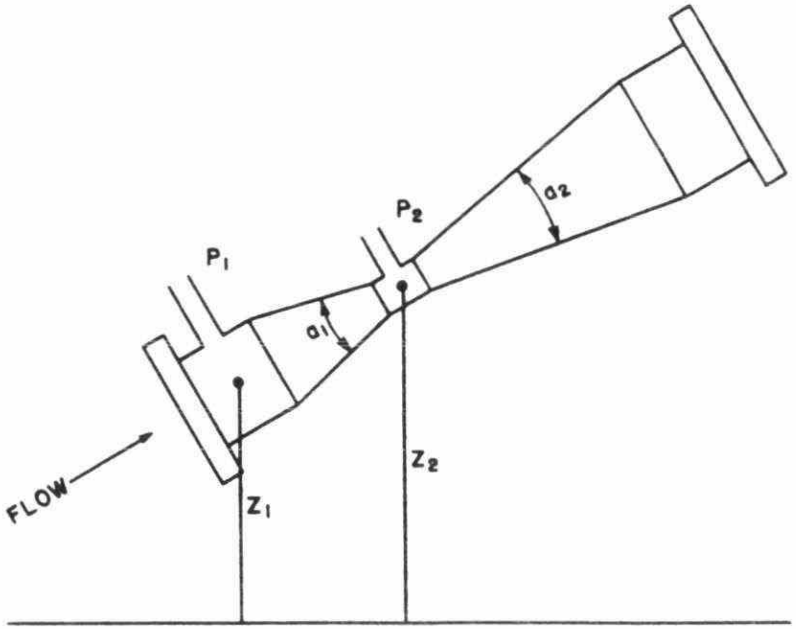


Figure 4-6
Venturi Tube Meter

(8) The Rotameter

The Rotameter is very popular in the chemical process industry. It consists of a 'float' which is free to move up or down in a vertical, slightly tapered tube having its small end down. The liquid enters the lower end of the tube and the float rises until the area between the float and the tube wall is such that the pressure drop across this constriction is equal to the weight of the float.

The tapered tube is usually made of glass and has a scale etched on it. Interchangeable, precision-bore glass tubes and metal tubes are available. Also, floats of different densities are available for use with different liquids. The manufacturer will usually supply a calibration curve for the rotameter for the various tubes and floats.

(9) Magnetic Flowmeter

To understand the principle of the magnetic flowmeter, it is necessary to review Faraday's law of electromagnetic induction. This law states that if a magnetic field is generated in one direction and a conductor is moved through this field at right angles to it, a voltage will be generated which is proportional to the speed of the conductor and the strength of the field.

Referring to Figure 4-7, if an electromagnet generates a magnetic field of constant strength at right angles through a non-magnetic flow tube, and a conductive liquid (water) is passed through the tube, a voltage will be generated which is proportional to the rate of flow of the liquid. Two electrodes placed diametrically opposite each other in contact with the liquid, but insulated from the tube, are connected to an instrument to read the voltage generated. The flow tube is generally lined with an insulating material to prevent shorting of the voltage. An alternating current millivoltmeter of special design can be calibrated to read directly in units of flow.

For all practical purposes, any liquid having a conductivity greater than 50 micromhos can be used in this type of meter. Most industrial wastes have conductivities greater than 100 micromhos and the meter is ideally suited for use with them.

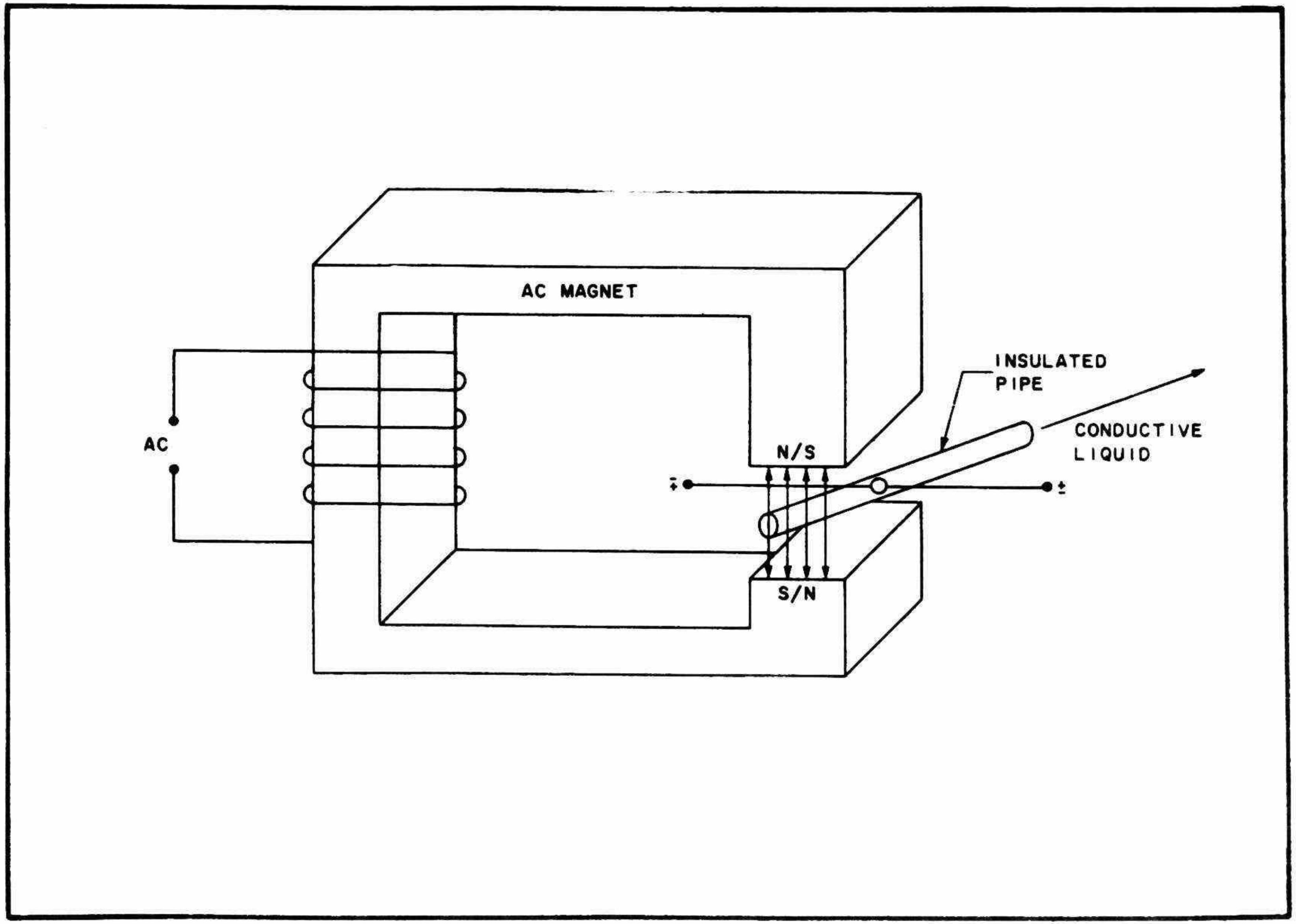


Figure 4-7
Magnetic Flowmeter

The magnetic flowmeter is more expensive than the orifice or venturi but has greater accuracy, no pressure loss, can be used with nearly all liquids, can be used in any position, and requires little maintenance.

(10) Turbine Meters

In this type of flowmeter, a turbine wheel or helical rotor is mounted on bearings concentrically in a pipe and parallel to the direction of liquid flow. The passage of liquid through the pipe causes the wheel to rotate, with the speed of rotation being a function of the flow. The rotating wheel is coupled either mechanically or electrically to a suitable metering device. This type of meter requires calibration, although this is usually done by the manufacturer.

FLOW MEASUREMENT IN OPEN CHANNELS

(1) Manning Formula for Open Channels

A liquid moving in a concrete drain or earthen ditch is subject to certain parameters which govern the flow of water in an open channel. These are:

(a) the slope of the sewer (hydraulic gradient)
(b) the width of the channel
(c) the depth of the water in the channel
(d) the roughness coefficient of the channel bed

Manning, in 1890, published an expression relating the flow in an open channel to these parameters:

$$Q = \frac{1.486}{n} \times A \times R^{0.67} \times S^{0.5}$$

where Q = flow (cubic feet/sec.)

n = roughness coefficient

A = cross sectional area (sq. ft.)

R = hydraulic radius = wetted perimeter (ft.)

S = slope of water level (ft./ft.)

Values for 'n' have been determined experimentally for various materials and are available in the literature.

For a uniform channel, the flow may be calculated by determining the depth, the channel slope, and selecting the appropriate roughness coefficient. The hydraulic slope, for all practical purposes, is equal to the channel slope in cases where the flow is uniform and where obstructions causing backwaters are absent. However, flows in most industrial sewers are too small and varied to be estimated accurately using the Manning formula so its application is limited.

(2) Weirs

The weir is the most common device used to measure flows in small open channels. A weir is a constriction placed in the channel having a known length over which the flow must pass. A relationship is established between the liquid flow and the head developed by the constriction. A weir may also be a depression in the side of a tank, channel or ditch, or it may be an overflow dam. Weirs are generally classified according to the shape of the notch; e.g., rectangular, triangular, V notch, trapezoidal, parabolic, etc.

The edge, or surface, over which the water flows is called the crest and the overflowing sheet of water is called the 'nappe'. The depth of water producing the discharge, 'H', is called the head. A weir with a sharp upstream edge so formed that the water springs clean of the crest is called a sharp-crested weir. If the nappe discharges into the air as in Figure 4-8, the weir is said to be free-discharging. If the discharge is partially under water as in Figure 4-9, the weir is said to be submerged.

(a) Sharp-Crested Rectangular Free-Discharging Weirs

The most widely used formula for the standard weir is the well-known "Francis" formula:

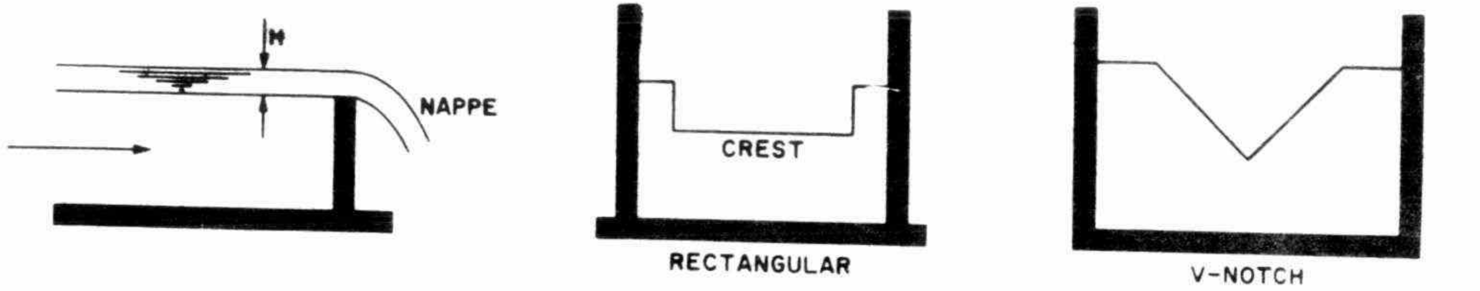


Figure 4-8
Sharp Crested Free Discharging Weirs

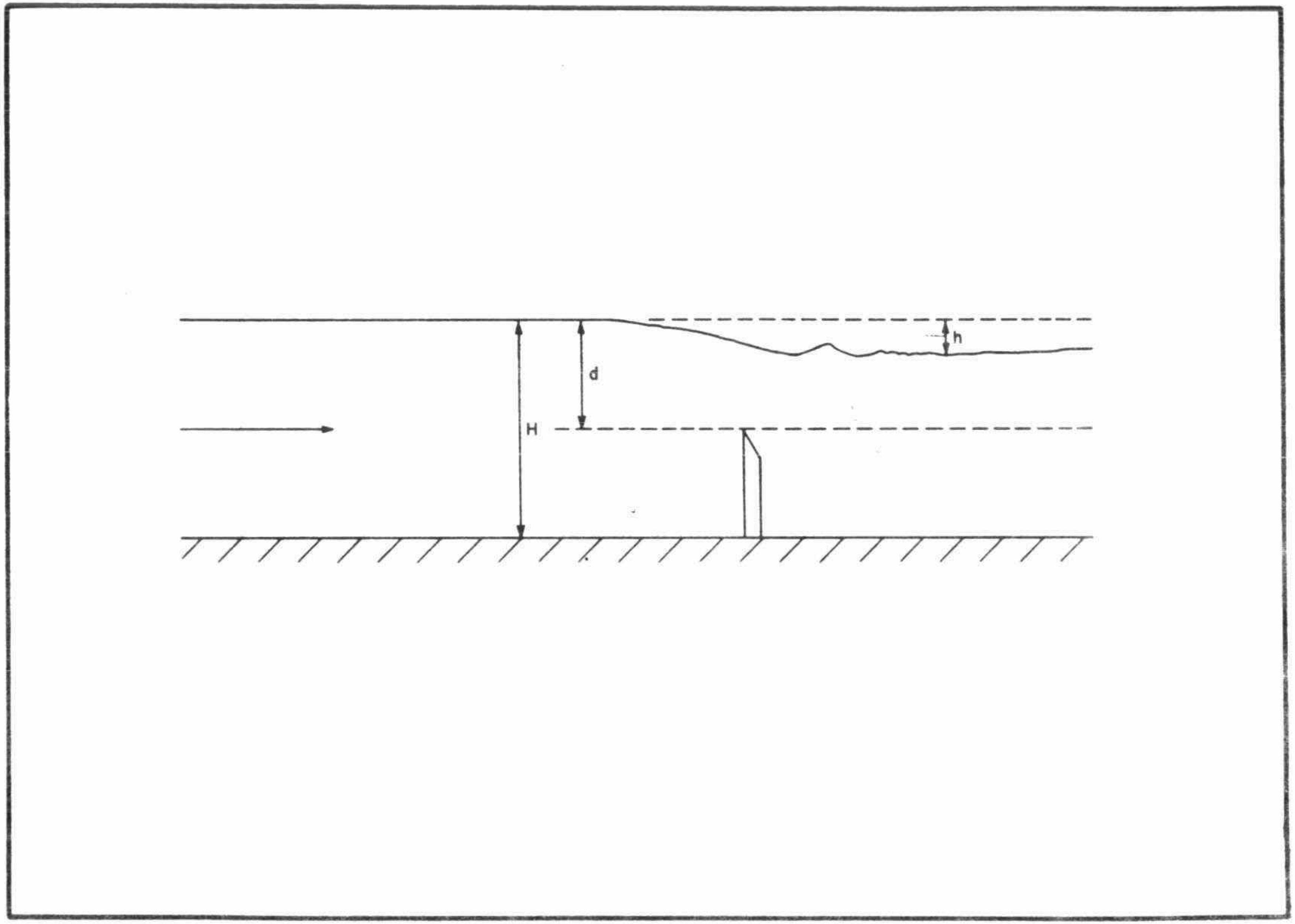


Figure 4-9
Submerged Weir

$$Q = C \times L \times H^{1.5}$$

where Q = flow (cubic feet per second)

L = length of weir crest (ft.)

H = head on weir (ft.)

C = a coefficient

Tables are available in most texts to solve this formula for various weir lengths. There are numerous other formulae available for calculating sharp-crested, free-discharging weir flows, each adding refinements to yield greater accuracy.

(b) Sharp-Crested 'V'-Notch Weirs

The triangular or V-notch weir is used for measuring small discharges where the rectangular weir becomes relatively insensitive to flow variation. 60, 90, and 120 degree triangles are frequently used. The formulae for computing the flow are:

$$Q = 1.44H^{2.5} \quad - \quad 60^{\circ} \text{ weir}$$

$$Q = 2.5H^{2.5} \quad - \quad 90^{\circ} \text{ weir}$$

$$Q = 4.33H^{2.5} \quad - \quad 120^{\circ} \text{ weir}$$

(c) Submerged Sharp-Crested Weirs

This type of weir is desirable when sufficient head is unavailable for selection of a more accurate weir or other measuring device. The discharge over such a weir is related to the upstream head, the downstream head, and the depth of submergence of the weir. The Francis formula approximates the flow when the weir is sharp-crested:

$$Q = C \times L \times \sqrt{h} \times (H + 0.38d)$$

where Q = flow (cfs)

L = weir length (ft.)

H = upstream weir head (ft.)

h = elevation drop $(H_1 - H_2)$

d = depth of submergence (ft.)

c = weir coefficient - generally = 3.33

(d) Broad-Crested Weirs

A weir is considered broad-crested when the head over the weir is less than twice the breadth of the weir. (Figure 4-10). These weirs do not provide the accuracy of flow measurement of a sharp-crested weir due to the inconsistency in establishing coefficients for all the types of broad crests. Characteristics such as rounding the ends of the broad crest, roughness coefficients of materials used and the shape of the water level over the crest are some of the factors that have to be considered in the evaluation of the coefficient. An approximation of the flow over most broad-crested weirs can be obtained by using the following formula:

$$Q = C \times L \times H^{1.5}$$

L = weir length (ft.)

where H = head on weir (measured at least 2.5H upstream from weir)

C = weir coefficient (equal to 2.63 where the weir head is greater than 1.5 feet)

(e) Cippolletti Weir

This weir has a trapezoidal cross-section with side slopes of 1:4 (horizontal to vertical). Figure 4-11. The slope provides sufficient additional passage area to compensate for contractions at the ends and adjustments for these contractions do not have to be made. The following formula can be used to approximate the flow through such a weir:

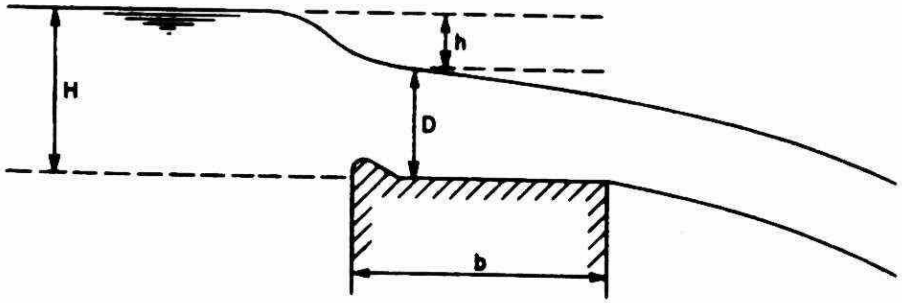


Figure 4-10
Broad-Crested Weir

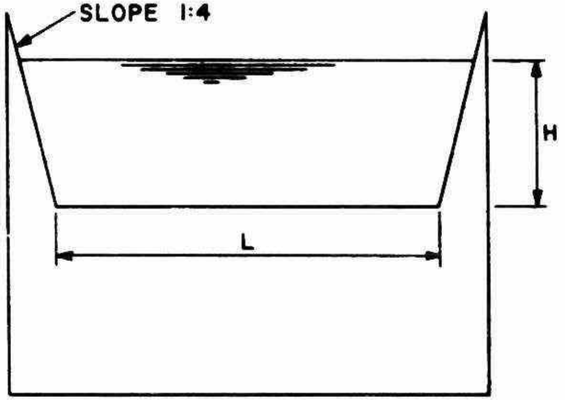


Figure 4-11
Cippolletti Weir

$$Q = 3.3 \times (C \times 2/3\ L) \times H^{1.5}$$

(f) Circular Weir

Stand pipes used to control tank level can be used to measure flow as they represent a circular weir. Circular weirs have no end contractions and, provided vortex action is not established in the stand pipes, the flow may be estimated by:

$$Q = 0.0243\ d \times h^{1.4}$$

Q = flow (cfs)

d = pipe diameter (inches)

h = head on weir 3-5 diameters back from overflow (inches)

Some of the limiting dimensions are shown in Figure 4-12.

(3) Velocity Measurement

If the average velocity of the flow in an open channel is known and the cross sectional area can be calculated, then the flow can be calculated from the formula:

$$Q = V \times A$$

where Q = flow (cfs)

V = velocity (ft./sec.)

A = cross sectional area of flow (sq. ft.)

A number of methods are available to measure the velocity.

(a) Stop Watch Method

In this method, the velocity of the surface waters is calculated by measuring the time it takes a floating object to travel over a measured distance. Wood chips, oranges, rubber balls, partially filled bottles, etc., may

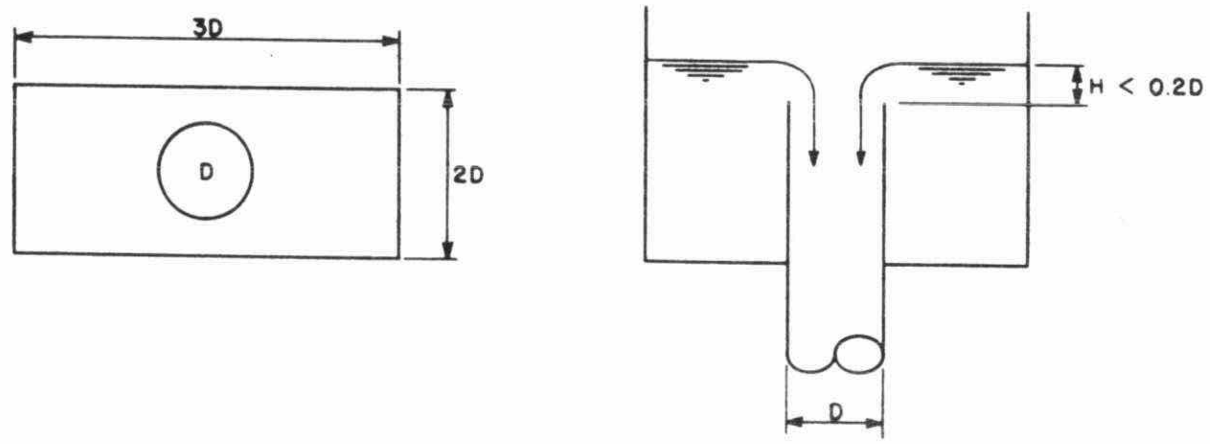


Figure 4-12
Circular Weir

be used with success. For most channels, the surface velocity is about 15 percent greater than the average channel velocity and the maximum velocity occurs at about 0.4 of the distance from the surface to the channel bottom.

This method gives a quick assessment of the flow.

(b) Current Meters

A number of companies manufacture devices which may be used to measure the velocity of flow in a channel or body of water. The two most commonly encountered are the Ott Meter and the Gurley Meter.

The Ott Meter consists of a free-rotating helical propeller mounted on a suitable support to allow it to be lowered into the water. The Gurley Meter is similar, except that the propeller is replaced by a set of rotating cups like those of a wind velocity meter. In operation, the rotating portion is lowered into the water and the revolutions per unit time are counted by some suitable means such as the transmission of a signal. The number of revolutions is proportional to the velocity of flow, and the actual velocity can be read from a calibration chart relating revolutions per unit time to flow. A number of velocity readings should be taken at various distances across the channel and at varying depths, then averaged to yield the average stream velocity.

These instruments are portable and are useful in checking flows where no built-in device is available.

(4) The Parshall Flume

Figure 4-13 shows the typical design and dimensions of the Parshall Flume. Because the flume has a contraction at the throat, the velocity of the liquid flowing through the flume is raised and any sand or silt is prevented from settling. Thus, the flume is to some extent self-cleaning, although deposits (slime growth, etc.) can build up on the sides which will affect the accuracy.

The flume consists of an open-channel venturi section, a converging inlet section, a downward sloping throat, and

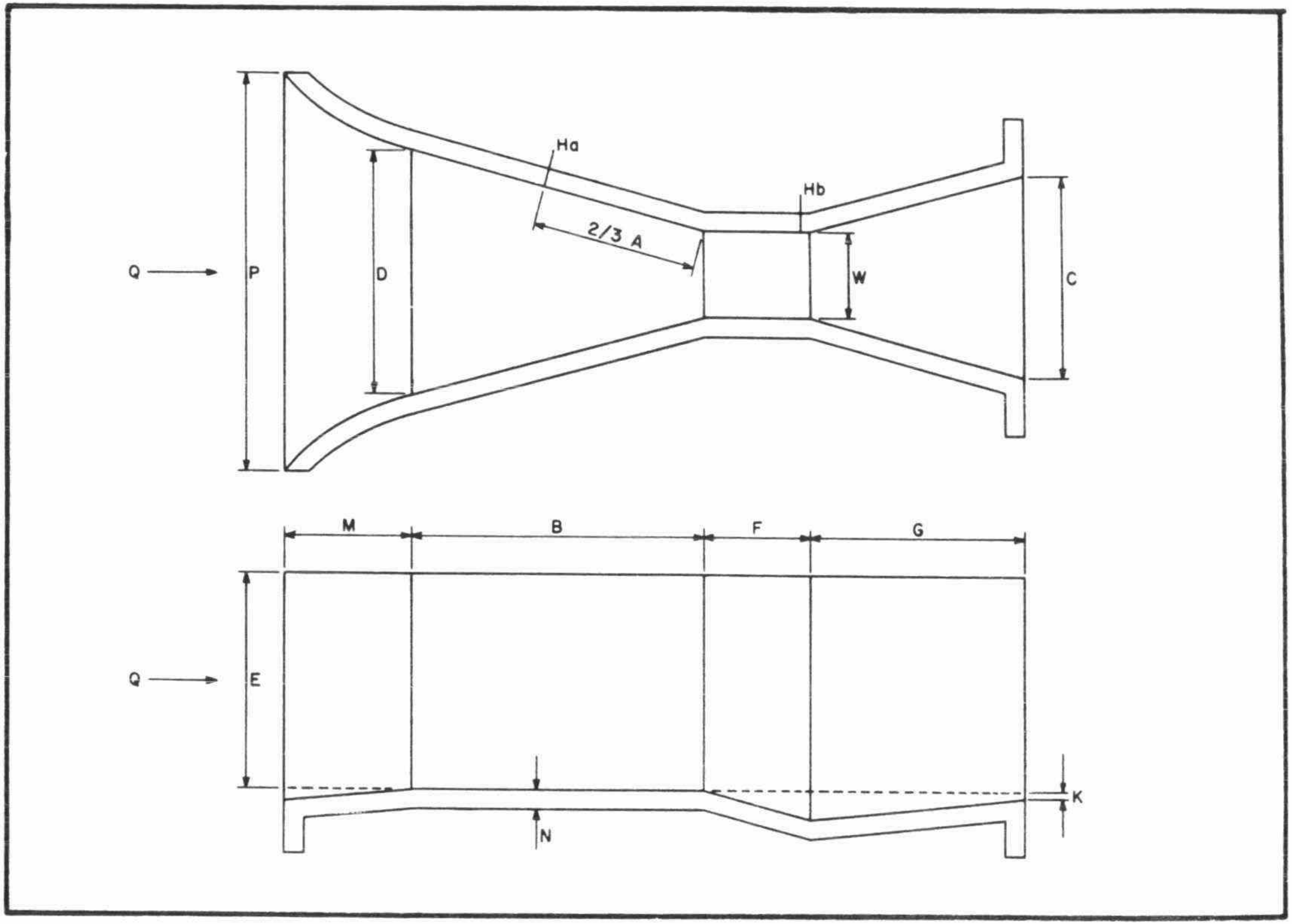


Figure 4-13
Parshall Flume

CHAPTER V

SAMPLING

Sampling plays a vitally important part in controlling industrial wastes. If it is not done properly, the conclusions drawn from an inspection or survey will be meaningless.

BASIC CONSIDERATIONS

(1) Representivity and Uncertainty

A sample is "a portion or part taken as representative of the whole". To be absolutely sure that a sample is representative, the whole body being sampled would have to be taken for analysis. This is impossible and a smaller portion must therefore be taken. The smaller the portion, however, the greater the uncertainty that the sample is representative of the whole.

The objective in sampling is to obtain as good a representation as is practicable. Generally, the more samples taken, the better the representation.

At some time you will be required to determine by sampling whether a particular discharge violates a by-law. Since legal proceedings may follow, the samples must be as representative as technolody will allow and the methods and procedures used in obtaining the samples must reflect this. At all times, the methods employed must result in the fulfillment of the objectives of the survey - with the smallest possible degree of uncertainty.

(2) Pre-Sampling Steps

The first step in planning the work is to review the objectives of the survey. For example, if it is decided that the prime purpose of the survey is to determine the quantity of a pollutant being discharged during a twenty-four hour processing day, there is no point in taking a single portion only. Many portions must be taken to assure representivity.

The second pre-sampling step is to observe the process or processes which give rise to the waste stream. Include a preliminary measurement of flow rates and their variation during the processing period and even, in certain cases, preliminary sampling of the waste. For example, if the process is one in which there are periodic dumps of high-volume, high-strength material, it would not be advisable to combine portions taken at intervals to form a single large sample, since the variations might cancel each other out.

Thirdly, determine the sample points. Use sewer diagrams to ensure that the chosen points will provide data consistent with the objectives of the survey. For example, if the objective is to determine the relative contribution of two process streams which merge, at least one sampling point must be upstream of the convergence. If a sample is taken downstream of the mixing point, it should be taken sufficiently far downstream to ensure that complete mixing has taken place.

Having carried out the above steps, and depending on the needs of the particular survey, record:

(a) the number and location of sampling points;
(b) the type of samples;
(c) the frequency of sampling;
(d) the duration of the sampling period;
(e) the analyses required; and
(f) any other pertinent factors, such as manpower and equipment requirements.

(3) Other Considerations

Samples may be obtained in many ways. The particular technique and equipment used in a given case will depend on the characteristics of the waste stream, the location of the sampling point, the type of sampling point, the type and size of the sample, the interval between portions of a composite sample and the duration of the sampling period. Other considerations may be the number of sampling points, the distance between sampling points and the availability of survey personnel.

Characteristics of the Waste Stream

The following characteristics must be considered:

(a) the velocity of the flow;
(b) the presence of floating liquids such as oil;
(c) the presence of heavy suspended solid material which may form a layer on the bottom of the sewer;
(d) the presence of heavy liquids upon which the water may float.

Use the correct equipment. With a waste stream of high velocity, a light metal or plastic sample container on a rope is virtually useless. If a sample is to be obtained at a given depth, the closed sample container must open when the desired depth is reached. A thick oil floating on water cannot be sampled using a narrow-necked bottle as the sampling device.

The characteristics of the waste stream must be carefully observed, their possible effects on the objectives of the survey must be considered, and the method and equipment used in sampling must be carefully chosen to eliminate errors and reduce uncertainty in the final result.

Location of the Sampling Point

The location of the sampling point is important to obtain a proper result. In certain cases, especially where merging streams are large and slow-moving, complete mixing may not be achieved for a considerable distance. If this is suspected, add a dye to one stream to determine the point of complete mixing. In another situation, where sampling is in a fairly large open channel, the sample should not be taken at the surface, nor at the bottom, nor at the sides. Rather, sample the flow in the middle of the channel and at approximately one-third of the depth. This will provide the most representative sample. Generally, sampling points must be established where the waste stream is as thoroughly mixed as possible. Locations where it may not be completely mixed include: immediately above a weir, immediately below a weir, immediately downstream of a sharp bend in a large sewer, etc. Careful observation of on-site conditions is essential if errors are to be avoided.

Type of Sampling Point

The method of sampling and the equipment to be used will also depend upon the type of sampling point. For example, the technique and apparatus needed to obtain a sample from a small, deep manhole will be quite different from those required to obtain a sample from the centre of the volume of liquid contained in a large tank. Again, obtain a sample as representative of the whole as possible. When sampling from a valve on a pipe, for example, the liquid should be allowed to run to waste for a few seconds before taking the sample to ensure that the escaping liquid is of the same quality as that flowing in the pipe at the time of sampling.

Type and Size of Sample

These considerations are quite straightforward and involve mainly the correct choice of equipment.

The interval between portions of a composite sample, the duration of the sampling period, the number of sampling points, the distance between sampling points and the availability of survey personnel all will affect your technique and your choice of equipment. The principles involved are specific to each case. They are, however, matters of common sense and should present no difficulty in the field.

TYPES OF SAMPLES

(a) Grab Sample

A grab sample is an aliquot taken in a single excursion of the sampling device into the flow being sampled. The amount taken is decided by the needs of the analysis. Recording the flow rate at the time of sampling is not necessary. A grab sample is useful in determining the characteristics of a waste flow at a specific time. It is not very useful for calculating a waste loading, since a single aliquot is rarely representative of average conditions. Therefore, it is generally used only where concentration limits apply.

(b) Composite Samples

A composite sample is one which is composed of a series of grab samples taken at inervals during the sampling period.

This type of sample represents the average characteristics of the waste flow over the survey period. Considered with the flow volume over the same period it may be used to calculate waste loadings.

Composite samples are of two types:

(1) those in which the grab samples are kept separate and analysed separately; and

(2) those in which the grab samples are combined together to form a bulk sample, all or part of which is subjected to analysis.

Both types enable the average characteristics of the waste flow to be determined but the first type also enables the variations to be clearly seen.

In the first type, a constant volume is taken at each interval regardless of the flow rate at that time. However, if a waste loading is to be calculated and the flow rate is not constant, a measurement of the flow rate must be made when each sample is taken.

In the second type of composite, where the portions are combined, a constant volume is taken at each interval only when it is known that the flow rate is constant. Where the flow rate is variable (as in most industrial processes), the volume of the portion taken at each interval must be in proportion to the flow rate at the time when the sample is withdrawn from the waste stream.

A constant time interval is usually chosen between portions of a composite sample, since most variations in waste characteristics occur on a time cycle. However, in certain cases variations may occur on a volume basis and the sample portions would then be taken at volume intervals (for example, one portion for each 1,000 gallons of flow).

The intervals between portions are determined by the variability of the waste characteristics. If the characteristics vary rapidly, the portions must be taken frequently. If the waste is of fairly uniform character, the intervals may be longer. The most accurate average will of course be given by a continuously drawn sample, but unless automatic equipment is used, this will be impractical. Therefore, longer intervals, such as 10, 15 or 30 minutes are often used. However, in no case should portions be taken less frequently than once per hour. A similar principle applies when characteristics vary with volume.

METHODS OF SAMPLING

Two general methods are available: automatic and manual.

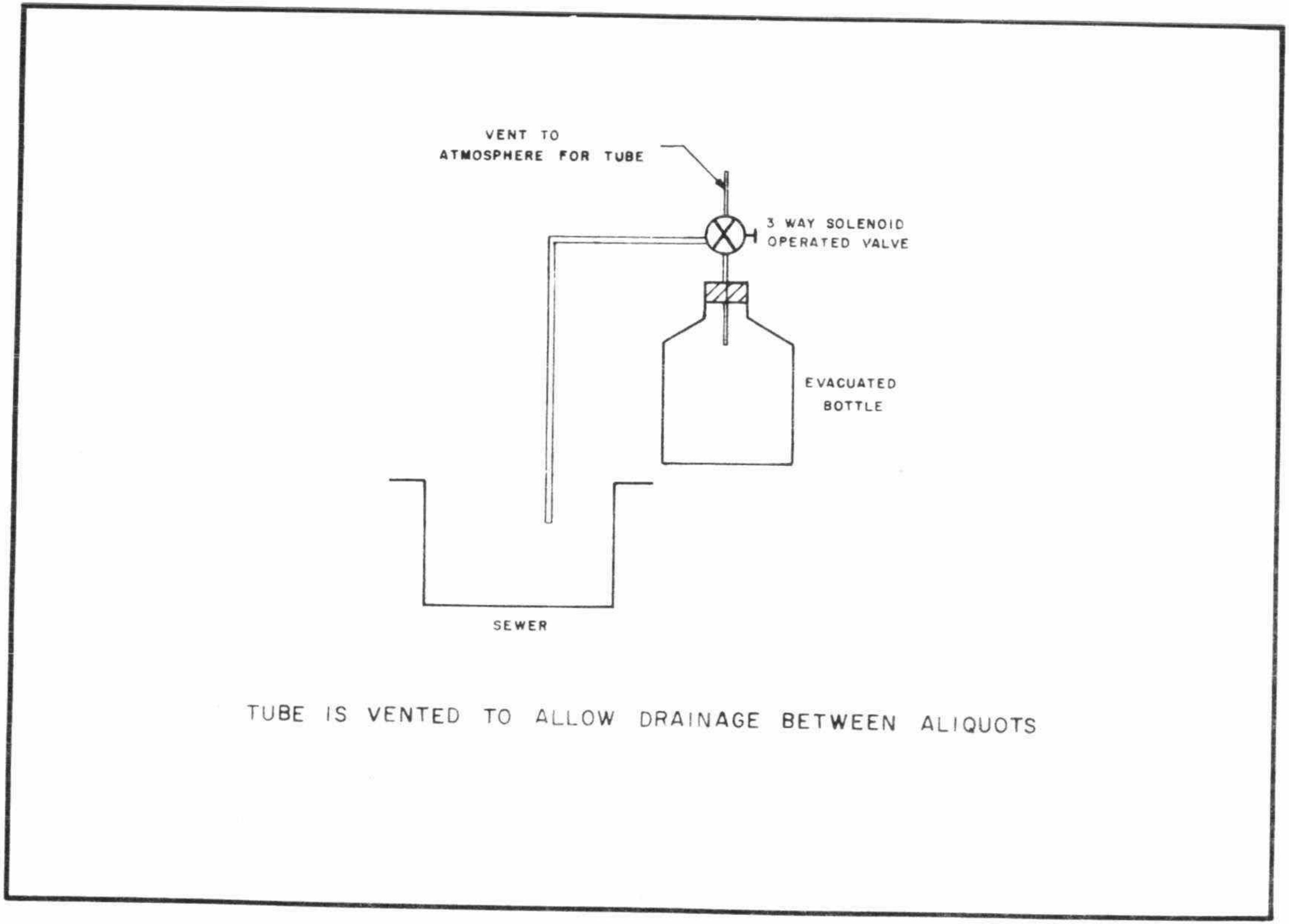
(1) Automatic

(a) Vacuum Sampler

This apparatus, shown in Figure 5-1, consists of an evacuated sample container, fitted with an electrically (or mechanically) operated stopcock and a length of tubing. The open end of the tube is placed in the waste stream and the stopcock opening mechanism is set to operate at the required intervals. When the stopcock opens, the sample is drawn into the container by the vacuum. The open period of the stopcock is set to give the required portion. In this simple form, only the "bulked" type of composite sample can be taken, but a variation of the equipment may be used: a number of small bottles are evacuated with each having a stopcock and sampling tube arranged to open in correct sequence, and at the proper interval, by a timing mechanism. This allows the collection of separate portions. They are kept separate for analysis.

Advantages of this type of apparatus include simplicity, low cost and ability to function for long periods on a small storage battery. Its chief limitations are that it must be used only with a short tube and that, for the greatest accuracy, it should be provided with a stopcock which will vent the tube to atmosphere between portions, allowing the tube to drain before the next aliquot is taken.

(b) Pump Sampler



TUBE IS VENTED TO ALLOW DRAINAGE BETWEEN ALIQUOTS

Figure 5-1
Vacuum Sampler

This type of sampler consists of a pump which transfers the sample from the waste stream to the sample container through a tube. A simple form is shown in Figure 5-2. As in the previous example, a timing mechanism may be used to control the intervals between portions and the size of the portions taken. Many types of pumps may be used. The most useful are chemical feed pumps, due to their ability to dispense small, accurately measured volumes of liquid.

A modification of the basic pump sampler is one in which the pump runs continuously, pumping the liquid from the sampling point, through the sampler, and out to waste. At the proper intervals, the desired quantity of liquid is withdrawn by a mechanical arrangement which diverts all or part of the flow through the machine into the sample container. Examples are shown in Figures 5-3, 5-4 and 5-5.

In addition to the above modification, as in the case of the vacuum sampler, a number of small sample containers can be filled instead of a single large container, depending on the type of composite sample required. Advantages of this type of sampler include simplicity, relatively low cost and ability to function on a small battery. As with vacuum samplers, they are limited by the necessity of using only a short tube (preferably vented to atmosphere between portions), or by having a continuous flow through the machine.

(c) Scoops and Wheels

In addition to those samplers which work either by vacuum or by pumping, there are many other types which are based on various arrangements of wheels, discs and rotating scoops. An example of these is shown in Figure 5-6. All types have advantages and disadvantages which should be considered before a selection is made for a particular survey.

(d) Instruments

Any consideration of automatic sampling devices should include: thermometers, turbidity meters, pH meters, oxidation-reduction potential meters, hydrometers, conductivity meters, and so on. These are useful sampling tools and should be used whenever necessary.

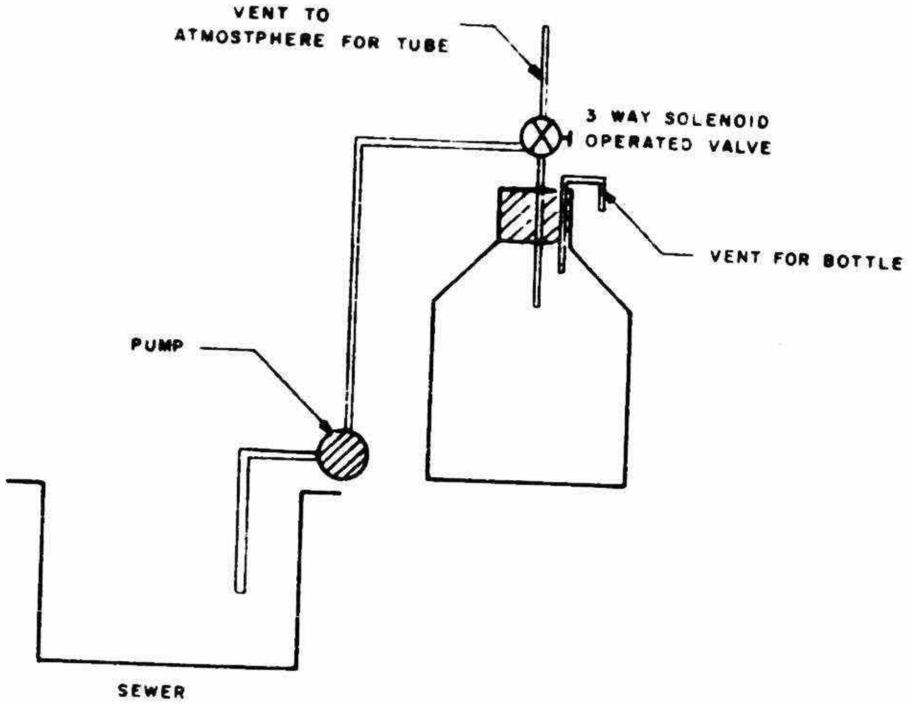
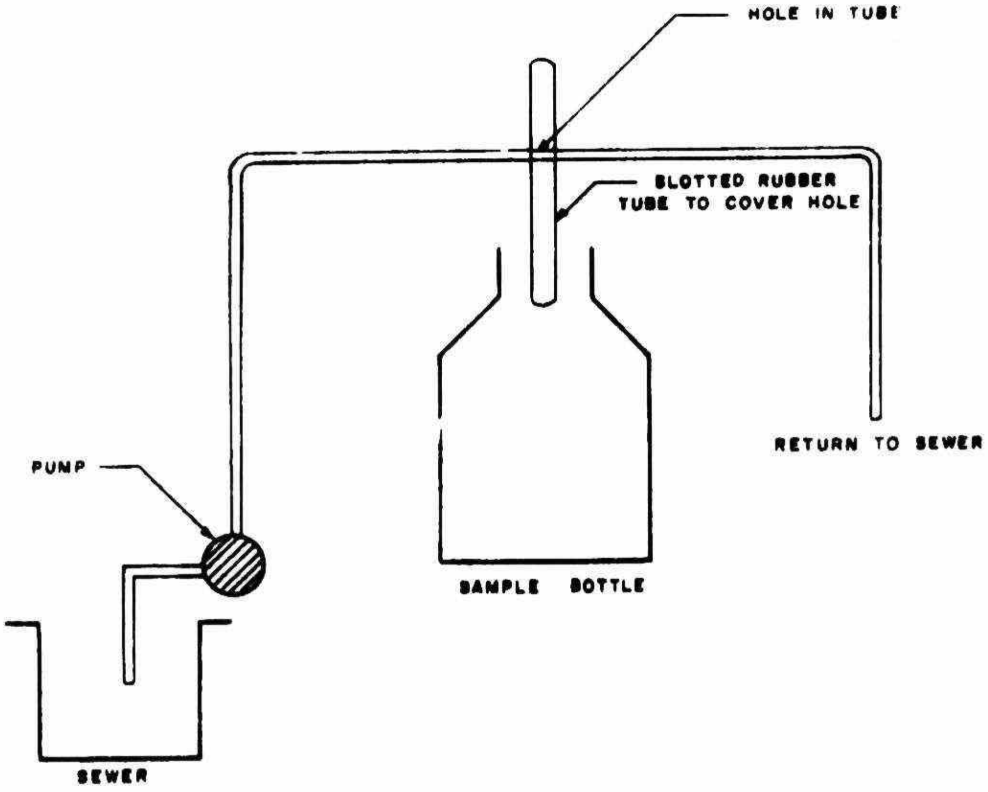
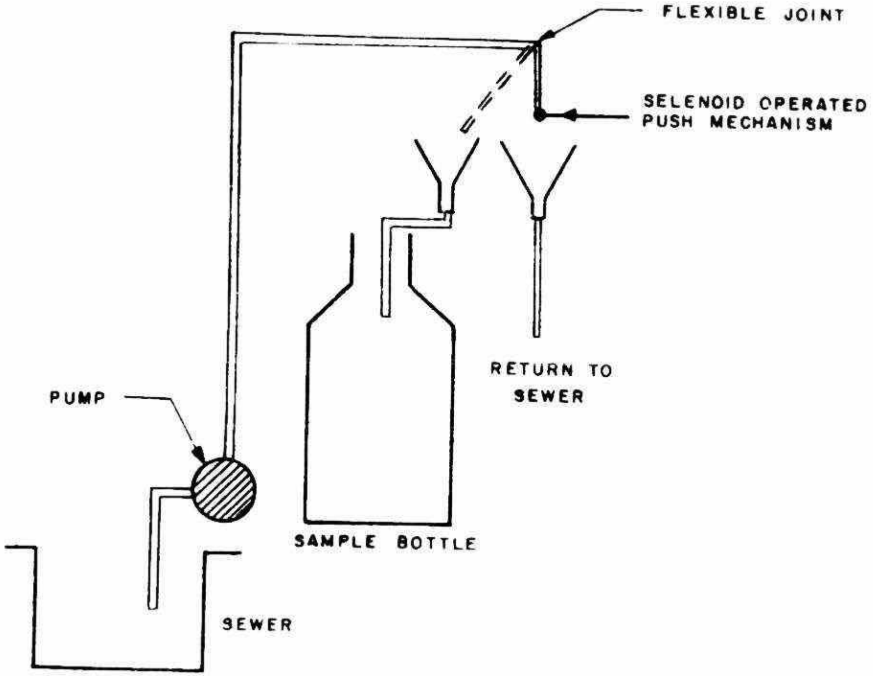


Figure 5-2
Pump Sampler



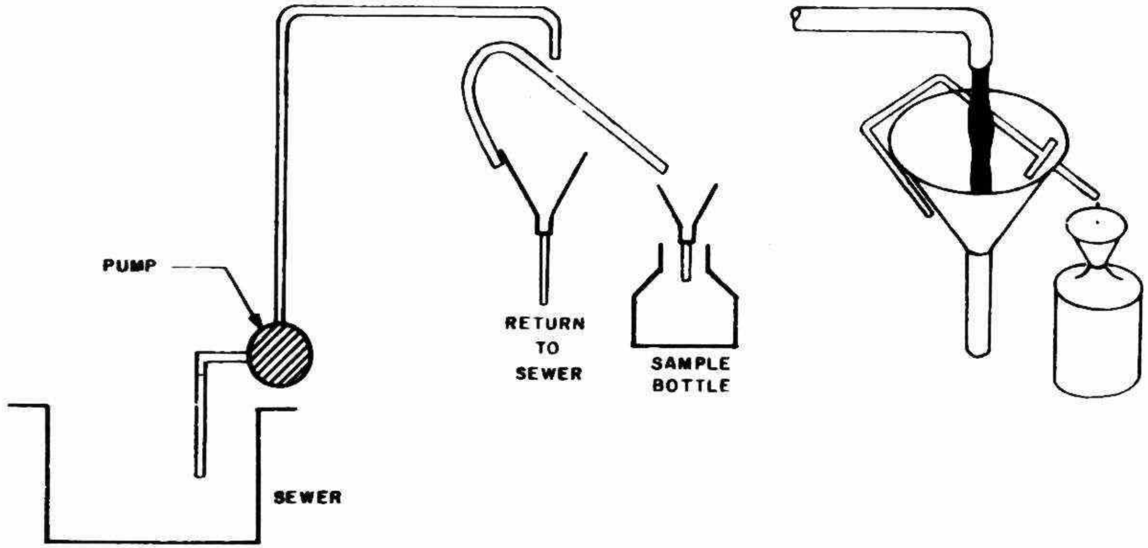
FLUID LEAKS FROM HOLE IN TUBE AND FLOWS VIA DRIP TUBE (SLOTTED RUBBER TUBE) INTO SAMPLE BOTTLE

Figure 5-3
Drip Tube Diverter



SOLENOID PUSHES TUBE OVER TO FUNNEL LEADING TO SAMPLE BOTTLE

Figure 5-4
Solenoid Diverter



WIRE ROD PASSES THROUGH FLOW AND CAUSES A SMALL QUANTITY OF LIQUID TO FLOW DOWN IT INTO THE SAMPLE BOTTLE

Figure 5-5
Funnel and Rod Diverter

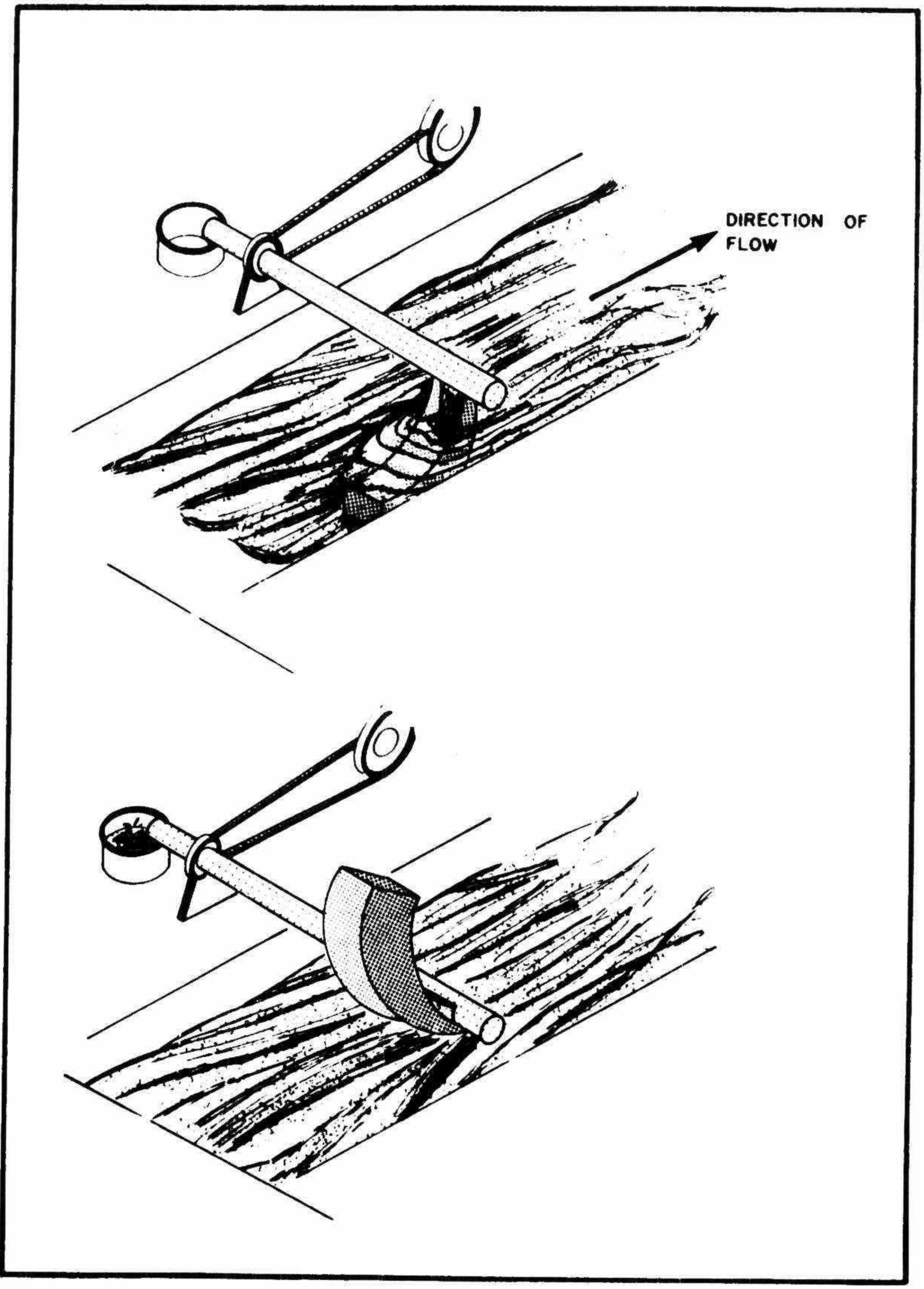


Figure 5-6
Rotating Scoop

(2) Manual

Equipment used in manual sampling is quite simple, consisting usually of a mechanical extension of the hand and arm. A manual sampling "kit" should hold buckets of various sizes and types, lines, poles (able to be joined together), bucket or bottle holders, and weights. Advantages of manual sampling include almost complete reliability and power of observation and decision. Its chief limitation is very high operating cost.

ANALYTICAL CONSIDERATIONS

(a) Selection of Sample Volume

In general, the largest practical sample volume should be taken. In no case should the amount taken be less than 120 percent of the volume required for the analyses. The surplus allows repeat analyses if necessary. Table A shows the sample volumes required for various analyses. These are based on the methods of analysis carried out by the Ministry laboratories.

(b) Selection of Sample Container

Glass or plastic containers are generally acceptable for the common run of samples which are encountered. Where a sample will be analysed for metals, a plastic container should be used, since certain metals tend to "plate" out on glass bottles. For most other elements, however, a glass container is suitable, but if the cap has a foil liner, it must be removed and replaced with a piece of plastic film when the bottle is used for metals. Whatever container is used, it must, of course be chemically clean.

(c) Transfer of Sample

When transferring a sample from the sampling device to the container, avoid spillage. A small funnel may be helpful. A minimum delay in transferring the sample is desirable, and it is also important that the whole volume of the portion taken be placed in the sample container. This is especially important in the case of a portion which contains suspended solids or liquids other than water because if only a part is transferred to the container an unrepresentative quantity

TABLE A

ANALYTICAL REQUIREMENTS

ANALYSIS	VOLUME REQUIRED (ml)	CONTAINER REQUIRED	PRESERVATIVE REQUIRED
Alkalinity	75	G or P	none
Aluminum	100	G^1 or P	none
Ammonia	75	G	H_2SO_4
Anionic Detergents	125	G	none
Antimony	400	G or P	none
Arsenic	50	G^1 or P	$none^2$
Barium	50	G or P	none
BOD	500	G or P	refrigerate
Boron	100	P	none
Cadmium	100	P^1	HNO_3
Calcium	100	P^1	HNO_3
Chloride	400	G or P	none
Chromium	100	G or P	none
Cobalt	100	P^1	HNO_3
COD	75	G	none
Conductivity	200	G or P	none
Copper	100	P^1	HNO_3
Cyanide	500	P	NaOH
Fluoride	350	P	none
Hardness	75	G or P	none
Iron	100	P^1	HNO_3
Lead	100	P^1	HNO_3

TABLE A (continued)

ANALYSIS	VOLUME REQUIRED (ml)	CONTAINER REQUIRED	PRESERVATIVE REQUIRED
Lithium	100	P	none
Magnesium	100	p[1]	HNO_3
Manganese	100	p[1]	HNO_3
Mercury	500	G[1]	$H_2SO_4 + KMnO_4$
Molybdenum	200	P	HNO_3
Nickel	100	p[1]	HNO_3
Nitrate	75	G or P	none
Nitrate	75	G or P	none
Nitrogen (Kjeldahl)	75	G or P	none
pH	25	G or P	none
Phenols	?[3]	G[4]	$H_2SO_4 + CuSO_4$
Phosphorus	75	G or P	none
Potassium	75	G or P	none
Selenium	500	G[1] or P	none
Silica	100	P	none[2]
Silver	100	p[1]	HNO_3
Sodium	75	G or P	none
Solids	500	G or P	none
Sulphate	250	G or P	none
Sulphide	50	G	$ZnC_2H_3O_2 + NaOH$
Tin	100	G or P[1]	none
Titanium	100	G or P[1]	none
Turbidity	150	G or P	none

TABLE A (continued)

ANALYSIS	VOLUME REQUIRED (ml)	CONTAINER REQUIRED	PRESERVATIVE REQUIRED
Uranium	10	P	none
Vanadium	100	G or P	none
Zinc	100	P[1]	HNO_3
Organic analyses	?[3]	G[4]	none

Note: G = Glass
P = Plastic

1. - if plastic is not available, glass bottles may be used only if the foil cap liner is removed and replaced by plastic and the sample preserved.

2. - it is essential that no nitric acid be used.

3. - as large a sample as practical.

4. - plastic must not be used and glass bottles must have foil lined caps.

NOTE:

(a) HNO_3 = nitric acid (concentrated). Add 10 drops to each bottle and mix well.

(b) NaOH = sodium hydroxide (caustic soda). Add two pellets to each bottle.

(c) $ZnC_2H_3O_2$ = zinc acetate. Add sufficient to form a good precipitate; ensure that there is excess sodium hydroxide present.

(d) H_2SO_4 = sulphuric acid (50% solution). Add 10 drops to each bottle.

(e) $KMnO_4$ = potassium permanganate (saturated solution). Add sufficient to maintain a purple colour.

(f) Cadmium, Calcium, Cobalt, Copper, Iron, Lead, Magnesium Manganese, Nickel, Silver and Zinc may all be determined on a single 400 ml sample.

(g) A 150 ml sample is required if both total and soluble phosphorus analyses are required.

(h) Total phosphorus and kjeldahl nitrogen may be determined on the same 75 ml sample.

(i) Soluble phosphorus, ammonia, nitrate and nitrite may be determined on the same 75 ml sample.

of the suspended matter may be left in the discarded portion. The sampling device should, therefore, be of a size which will allow use cf the whole portion.

(d) Perishability of Samples

Ideally, all samples should be subjected to analysis as soon as possible after collection. Where this cannot be done, the samples may be preserved to prevent deterioration. All samples are more or less perishable, bacteriological and biological samples being the most critical. In fact, the collection and handling of these samples are so specialized that no previous mention of them has been made. Before taking these samples, seek expert advice. Samples for chemical analysis are less sensitive, although certain parameters, such as dissolved gases and temperature, are very unstable and must be analysed for in the field. All samples should be kept cool, especially those for BOD analysis. (Samples should be protected from freezing, as this often alters certain characteristics). Table A shows a list of preservatives which may be used. Bear in mind, however, that if a preservative is added to a sample, it may interfere with analyses for substances other than the one preserved. Therefore, if more than one test is to be carried out on a sample, two portions should be taken and preservative should be added only to one.

(e) Identification of Samples

Samples must be properly and accurately labelled or otherwise marked to permit identification. The information required for each sample consists of:

(1) location of survey - municipality, name of company;
(2) date;
(3) location of sampling point;
(4) type of sample;
(5) duration of sampling period;
(6) time at which a grab sample is taken;
(7) intervals between portions of a bulked composite sample;
(8) nature and quantity of added preservatives;
(9) names of sampling personnel;
(10) container number.

This information should be recorded both on the bottle and in the field notebook. The container number should be marked at several places on the bottle, not only on an attached label. The sample can then be identified if the label is inadvertently removed. The bottle should be clearly marked if it is suspected that there is a high concentration of toxic material in the sample. This will alert the analyst and avoid accidents in the laboratory.

SAFETY IN SAMPLING

It is a fair statement that no sample is worth obtaining at the risk of life and limb.

Physical safety is a matter of instinct, but in unusual situations, such as may be experienced in survey work, actual or potential danger may not be recognized. Also, it is true that familiarity often breeds contempt, sometimes with tragic results.

The following are a few observations on personnel safety:

(1) Wear a life jacket when sampling from a boat.

(2) When sampling from a river bank, make sure that the bank is stable and not eroded.

(3) Never sample alone at night.

(4) Never enter a tank or other vessel or a sewer unless it is unavoidable, and then only when you are sure that the atmosphere is free of noxious gases and that there is no possibility of any material entering while sampling is in progress. Never perform this procedure alone and always use a life line.

(5) Always remember that most organic liquids are highly inflammable and form explosive mixtures with air. Smoke only in safe places.

(6) *Assume all chemical substances are noxious (until otherwise proven) if ingested into the stomach or lungs, or by contact with the skin and eyes. It is vital to know what materials may be encountered during a survey and to use all necessary protective devices.*

CHAPTER VI

CONDUCT OF INDUSTRIAL WASTES SURVEYS AND INSPECTIONS

Industrial wastes vary from industry to industry, from plant to plant, and from day to day. In order to deal with an existing or potential problem effectively, it is necessary to study the plant site in question.

An inspection is much less comprehensive than a survey. It may or may not be carried out with prior knowledge of the industry. It may vary from only a visual inspection of the sewer and effluent to obtaining composite samples for detailed analysis.

An industrial wastes survey is more complex and includes gathering of data on the processes, production, operating schedule and by-products as well as wastes emanating from a plant. It takes into account variations in flow rates, in strength and in characteristics of batch dumps, etc., and is normally carried out over a longer period than an inspection. The survey is approached in three parts: pre-field survey work, field survey work and post-field survey work.

PRE-FIELD SURVEY WORK

The amount of pre-field survey work required varies and depends largely on how much the surveyor knows about the type of industry and the plant in question. It also depends on the size and complexity of the operation(s). Before visiting the plant, learn as much as possible about the plant's activities (check with the Industrial Commission, the Public Utilities Commission, etc.) then refer to technical literature for more detail, particularly the water use and waste production.

As a first approach, refer to a text covering manufacturing process, etc., of the type of industry in question. Such texts include "The Chemical Process Industries" by R. N. Shreve, "Electrofinishing" by M. A. Brimi and J. R. Lock, "Electroplating Engineering Handbook" edited by A. K. Graham and "Modern Dairy Products" by L. M. Lampert. Keeping the material and bibliographies contained in the texts, in mind, refer to technical journals, conference proceedings (e.g., Purdue and Ontario Industrial Wastes Confer-

ences) and other sources to learn more about the process operations, nature and volume of wastes to be expected, etc.

FIELD SURVEY WORK

Armed with a good working knowledge of the industry, the surveyor is able to ask the appropriate questions of plant management and collect relevant data in an efficient manner.

Contact is made with management at a decision-making level. Also, throughout the survey, question individuals who are fully familiar with technical matters within the plant. Do not waste your time dealing with the man who parks the chief's car.

On initial contact, explain carefully to management the purpose of your visit and the reason it is necessary. Ask for full cooperation. Having secured their attention (and hopefully their cooperation), begin your survey by acquiring data specific to the plant in question.

Data obtained should include a description of all raw materials used and intermediate and final products produced, because these are the materials which may appear in the waste discharge. In addition, note production rates, the amount and source of water used, the plant operating schedule and the number of employees on site.

Then, with management and/or plant technical staff review the production process and determine the distribution of water within the plant. Any processes utilizing water should be examined in detail, especially where water is in direct contact with raw materials, products, etc. The nature, volume and point of discharge of the wastes from these processes must be clearly established. Frequent reference to up-to-date sewer maps and plant layout maps will prove invaluable. Obtain copies of these from the company management.

Processes which may result in spills or in batch dumps of materials require close scrutiny. Such discharges can have severe adverse effects on a municipal sewerage system if not handled properly. Note that such discharges are not always associated with water use.

During the review of the process, carry out a mass balance if possible on materials arriving at and leaving the plant by conventional means. Any difference will often give a close approximation of the quantity and type of air and water-borne wastes.

As the process review advances, the sampling and flow measuring points necessary to establish the characteristics of the wastes become clearly identified. These should be confirmed by a tour of the plant. Note general housekeeping conditions, sources of waste which may have been overlooked during previous discussions, discrepancies in sewer lay-outs, etc. In some cases, dye tracing studies to confirm or check sewer systems may be required.

Although municipal by-laws usually deal in concentrations of waste parameters only, the total loadings in pounds per day of a particular component is of concern. Obtain representative samples of the waste flow under consideration and accurate flow data over the period of sampling. Without such data, it is difficult to discuss the waste disposal situation intelligently. Large sums of money could be wasted on needless or inappropriate treatment facilities. Subsequent legal proceedings against the municipality could prove to be embarrassing. Also, non-equitable sharing of municipal waste treatment costs could occur. Thus, good common sense must prevail when it comes to sampling and flow measuring.

In many situations, existing public utility water meters and manual sampling provide the necessary data. In more complex situations (i.e., several outfalls and variable flows), more sophisticated equipment or techniques may be necessary, such as automatic samplers (which sample proportional to flow), portable weirs, or equipment for flow measurement by salt dilution techniques. In other situations, it may be necessary to have the company install permanent sampling and flow measurement and recording equipment, particularly where industrial waste surcharges may be assessed. There are some advantages in taking your own portable monitoring and recording equipment along to install in sewers for irregular periods (e.g., pH and conductivity probes).

The efforts required to obtain samples and flow measurements or estimates will depend largely on the purpose of the survey. Often, an order of magnitude is all that is required (i.e., for routine surveillance). In such cases, simple techniques are enough. If by-law enforcement, industrial waste surcharge calculations, treatment facility design, etc., are factors under consideration, the necessary information must be accurate and a more complex survey is needed.

In addition to your knowledge of hour-to-hour variations in waste characteristics and flows, find out about day-to-day, week-to-week or seasonal variations which may occur. For example, establishing the nature and volume of wastes at a canning factory when peas are being processed in June, will be of little value in assessing the situation in August and September when corn and tomatoes are being processed. Pre-field survey work plays a critical part in obtaining and assembling the total picture.

Once sampling locations are established and appropriate samples and flow data are obtained, have the samples analyzed in a qualified laboratory.

In some cases, preservation of samples with appropriate chemicals may be necessary (i.e., phenol, sulphides and cyanide-bearing samples should be preserved). In other cases, refrigeration of samples is desirable. In all cases, there must be no time lost between sampling and analysis. Communication between the laboratory staff and survey personnel prior to sampling is very useful and necessary to minimize delay in analyzing the samples.

POST-FIELD SURVEY WORK

Having returned to the office with the information obtained from the industrial representatives, and having received the analytical data from the laboratory, assess the data and, write a report. Prepare a standard report format and follow it in every case to eliminate overlooking important items. The format generally followed by the Industrial Wastes Branch of the Ministry of the Environment is shown in Figure 6-1. The report should be written as soon as possible after completion of the survey.

In reviewing the material, examine the analytical data carefully to see if the results are consistent with visual observations and anticipated results.

FIGURE 6-1

REPORT FORMAT

Introductory Paragraph - with reasons for survey, general background, etc.

SUMMARY

DETAILS OF SURVEY

Introductory Paragraph - with date, time, etc.

Personnel Participating

Personnel Interviewed

Description of Plant and/or Process(es)

Production and Operating Data

Water Consumption and Distribution

Sources of Liquid Wastes, Treatment and Disposal

Sampling and Analysis

WASTE LOADINGS AND PRODUCTION RELATIONS

DISCUSSION OF FINDINGS

CONCLUSIONS, REMARKS AND RECOMMENDATIONS

Signature

REFERENCES

APPENDICES

These results can be cross-checked on the basis of expected waste loading tc production ratios, material balances, volume of water used, etc. If the conclusions seem questionable, repeat the analysis. In some cases, it may be necessary to obtain more samples. Some situations initially show a company to be discharging more material to a watercourse than it received at the plant site. Usually a reasonable explanation of such results can be found and it is not always the fault of the flow measurement and sampling techniques used.

When satisfied that the data are reliable, compile and interpret them. A discussion of the results (the visual observations, etc.), and conclusions and recommendations are outlined. In some cases, the report may be very short and in others much longer, depending on the purpose of the survey, the complexity and size of the industry, and the degree of waste control already provided.

There is little use in doing all this work unless recommendations are followed up. Inspections or surveillance visits prove useful in the follow-up stage and remind the industry that they have not been forgotten.

CHAPTER VII

BREWERIES, DISTILLERIES AND WINERIES

The title of this section could well have been "The Fermentation Industry", which is the usual classification used in textbooks dealing with industrial processes and wastes. However, in Ontario, the fermentation industry consists essentially of the breweries, distilleries and wineries, since there are only two other plants using fermentation (to produce auromycin, declomycin and vinegar). There are other industrial processes that might, in the broadest of terms, be classed as fermentation processes, such as those making buttermilk and yogurt in dairy operations, and digester operations at sewage treatment plants. However, in all cases these latter processes use strains of bacteria to effect the desired conversions instead of yeast used by the true fermentation industries.

An industry closely associated with the alcoholic beverage industry, especially the breweries, is the malting industry which converts barley to malt and, in doing so, generates potent wastes.

Production of alcoholic beverages has been practised for centuries. In spite of this, the process is still as much an art as it is a science. For this reason, the producers are reluctant to change their methods and procedures. There have been refinements and increased recovery of by-products, which has lessened waste loadings, but the basic operation has changed very little. Any break-through in process modifications to reduce waste loadings, or in the handling of wastes, is unlikely.

With the exception of two distilleries and one winery, the industry in Ontario presently discharges its wastes into municipal sanitary sewer systems. This offers several significant advantages: It reduces the number, but results in larger more economical sewage treatment plants. It ensures adequate operation of the treatment facilities, because the municipal sewage treatment plant staff is concerned only with the operation of the plant. In a private industrial waste treatment plant, the operator also has production responsibilities which have priority over the waste treatment plant.

BREWERIES

Processes and Sources of Wastes

Figure 7-1 represents a simplified flow sheet for a brewery.

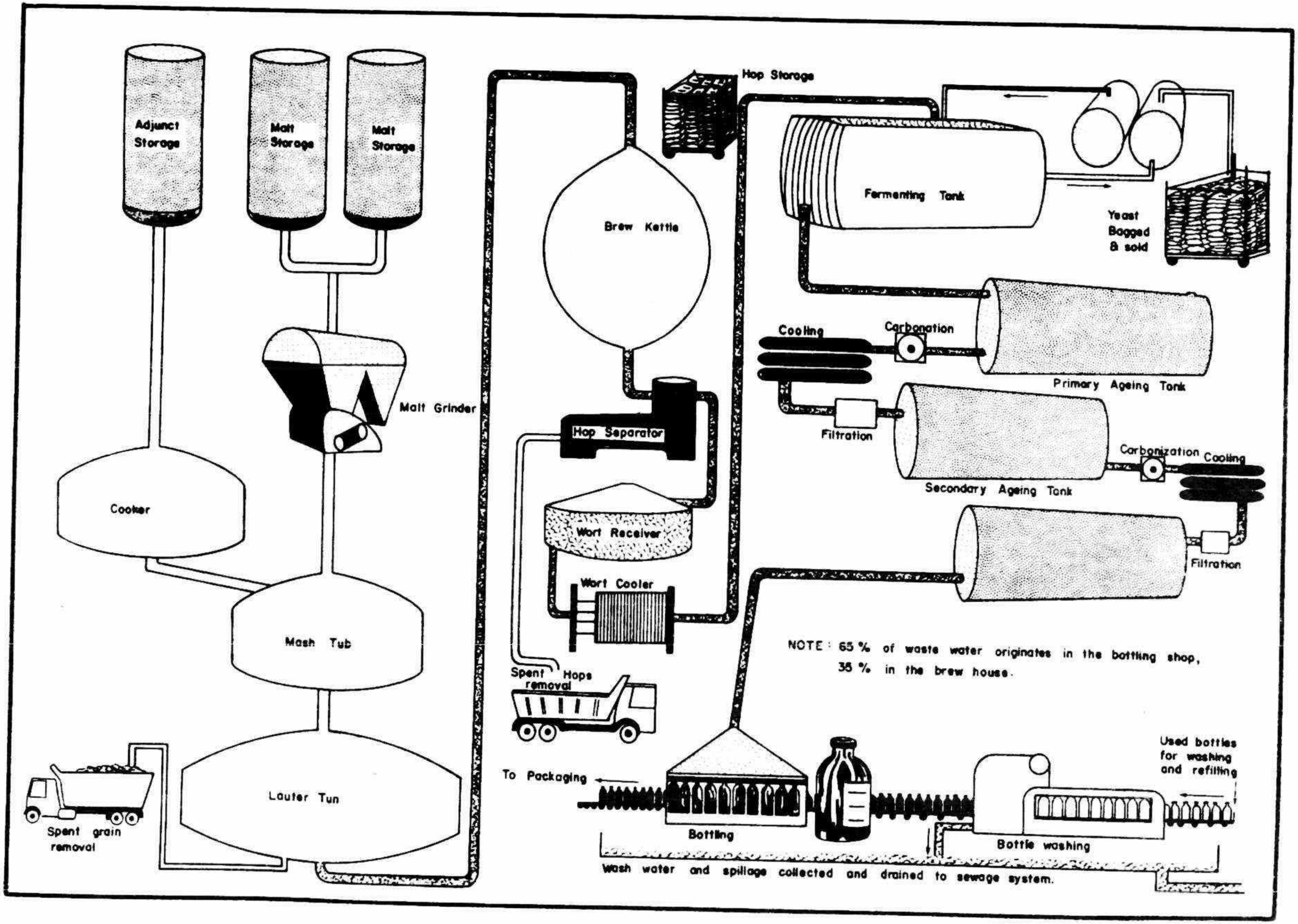
(1) Water Treatment

A vital part of the process at a brewery is played by the water treatment system. Since the final product, beer, is nearly all water, and the product is not distilled, the quality of the water used is extremely important. Depending on the raw water supply, the treatment required varies from dechlorination by carbon filters to more elaborate systems, the most common being de-ionization. De-ionization is a 2-stage ion exchange process, similar to household softeners, and is the source of the first major waste stream. When the ion unit is regenerated, strong acid and caustic are used and end up as wastes. If both units were regenerated at the same time, the resulting acid and caustic wastes would neutralize each other. However, the regeneration cycle does not permit this and the resulting wastes have a pH that varies from 2 to 12 within a period of 30 minutes. These wastes must be treated. Retaining the strong wastes for mixing and mutual neutralization is one approach, but additional caustic is usually needed to ensure adequate pH control.

(2) Brew House

The first part of the process consists of the mill, cooker, and mash tub. Here, a solution from the components in the malt and grains, or cereals, is formed, and an enzyme conversion makes the solution amenable to fermentation.

Everything is transferred from unit to unit until it reaches the lauter tun. There, due to a false bottom or screen, the solution (wort) is separated from the spent grains. The spent grains are a valuable by-product, sold as cattle feed. In spite of this by-product recovery, this area is a major source of waste because the liquid BOD can be as high as 25,000 ppm. Also, some breweries dry (or partially dry) the grains, sending the removed moisture to the sewer and increasing the sewer loading. Spraying of the spent grains (displacing the wort with



NOTE: 65 % of waste water originates in the bottling shop,
35 % in the brew house.

Figure 7-1
Flow Chart - Brewery

fresh water) improves the brewery's recovery of wort and also reduces the wastes produced in this area.

The wort and hops are taken to the brew kettle, and discharged through the hop jack after brewing. The hop jack acts like a filter, as did the lauter tun, and removes the hops, which are hauled away to land fill, or used as animal feed.

(3) Fermenting

Finally, the wort is ready for fermentation. It is cooled, added to the fermenters, and the yeast is introduced. This is usually the largest source of BOD from the brewery because excess yeast is formed during fermentation. Most yeast is sewered directly from the fermenters. However, the remaining processes (aging, storing and filtering), ensure that the final product is crystal clear. Thus, yeast and other protein materials are waste from this section of the process, to be discharged as sludge from the filters or washed from storage tanks.

(4) Bottling

Bottling is a significant waste source. From 50 to 75 percent of the water used in a brewery can be discharged as waste from the bottling operation. Bottles returned to the brewery are cleaned inside and out with caustic, rinsed, filled, sprayed with hot water to pasteurize them, then sprayed with cold water to complete pasteurization and cool the bottles. The wastes can have a high pH, but usually the caustic solution is recycled through a screen to remove labels, cigarette butts, etc., resulting in a batch discharge that must be adequately handled.

(5) Variability

Brewery wastes are extremely variable. With the exception of the bottling machine, all processes are batch operations, resulting in batch discharges of wastes. In a very small operation, one batch per day may pass through the brew house. Fermentation may last several days and aging may last several weeks. So none or several units may be emptied and cleaned out on any particular day. Production varies, depending on the season. In addition, there is a weekly variation. On Monday, everything in the brewery is clean and ready to go. By Friday, the normal shutdown day, accumulations and carry-over of washing operations have increased the daily loadings. These variations double the daily waste loadings later in the week.

Waste Control

To give an order of magnitude to the size of breweries, a very small operation would produce 1 batch (brew) of 2,500 gallons per day, or 20,000 barrels per year, while the largest would approach 125,000 gallons per day, or 1,000,000 barrels per year. (These values are guidelines only.)

The following table gives average values for the Ontario breweries and are the result of a survey carried out a few years ago. The values are calculated per barrel of beer (approximately 25 gallons).

Waste Flow	300 gallons	
BOD	2.7 pounds	900 ppm
Suspended Solids	1.8 pounds	600 ppm

Treatment of wastes from a brewery should be considered from the following viewpoints:

(1) treatment of wastes that must be controlled

(2) reduction in organic strength

(3) reduction in hydraulic loading

(1) Treatment of wastes that must be controlled involves pH control for water treatment wastes, caustic boil-out solutions used for clean-ups in the brew house, and soak solutions and caustic rinses in the bottling area. No matter what the method of final disposal, the pH of these wastes must be controlled.

(2) Reduction of organic loading includes a review of the spent grain and hops for efficient operation, the promotion of by-product recovery, (especially yeast), the

removal of filter cakes in dry form, and a continued attempt to reduce and eliminate accidental losses from operational errors and leaking equipment.

(3) A reduction in waste flow will not affect the organic loading, and will, in fact, increase the concentration of waste ingredients. Consider the segregation of uncontaminated flows for discharge to the storm sewer. This includes the neutralized water treatment wastes, cooling water from the wort cooler, fermenters, compressors and refrigeration systems. In addition, some segregation on the bottling machine should be possible. After the bottles are filled, the initial spray could be collected as contaminated wastes with the subsequent hot and cold sprays segregated for discharge to the storm sewer.

Methods of Waste Disposal

All breweries in the Province presently discharge their wastes to municipal sanitary sewer systems.

Biological treatment systems (stabilization lagoon, aerated lagoon, conventional activated sludge, or trickling filter) appear to be the only practicable methods of treating brewery wastes to substantially reduce the organic strength. While one company did operate a non-effluent treatment system (spray irrigation), few of the remaining breweries are located where enough land is available at a reasonable cost to make this an economic alternative.

With the exception of one municipality, no surcharges are being applied for overstrength wastes. Even with the growing trend to control industrial wastes in municipal systems and to apply surcharges for over-strength wastes, the breweries will likely continue as they are and pay the surcharge. In many respects, this is the preferred approach. The expertise of brewery personnel is in making beer while that of sewage plant personnel is in treating sewage.

DISTILLERIES

Distilleries and breweries have many similarities but the approach to by-product recovery is quite different.

The size of the plants in Ontario varies from 1,000 bushels per day of grain (mainly corn) and 150,000 gpd of water, to use in excess of 10,000 bushels per day and some 8 million gallons per day (mgd) of water.

Processes

The simplified flow sheet for a conventional distillery, Figure 7-2, indicates there is not an elaborate water treatment system at the beginning of the process. While water quality at this point is important, it is not critical since the product will be distilled.

The initial part of the process, the mill, cooker, and drop tun, serve the same purpose as in a brewery: to put the material into solution and effect an enzyme conversion so that the yeast can produce alcohol. Here is a major difference with respect to brewery operations: the spent grains are not separated. The entire mash is cooled and added to the fermenters with the yeast. Following fermentation, the entire contents are pumped to the beer still where the alcohol and volatile components are distilled off and the remainder, including the spent grains, drops out at the bottom as "slop". The overhead material is further distilled to separate the product which is aged, blended, cut and bottled.

In a distillery, a water treatment system is needed at the end of the process. It is usually a demineralizer to produce the good quality water required for cutting or diluting the final product.

Bottling in a distillery is considerably different from that carried out at a brewery. It is a dry operation since the bottles used are new, not washed, and the filling operation is closely controlled.

Sources of Wastes

(1) Cooking

The first source of wastes is relatively minor and originates at the cooker. Cooking is done under pressure; when the cooking cycle is completed, the pressure is released and a vacuum applied to the vessel. This allows

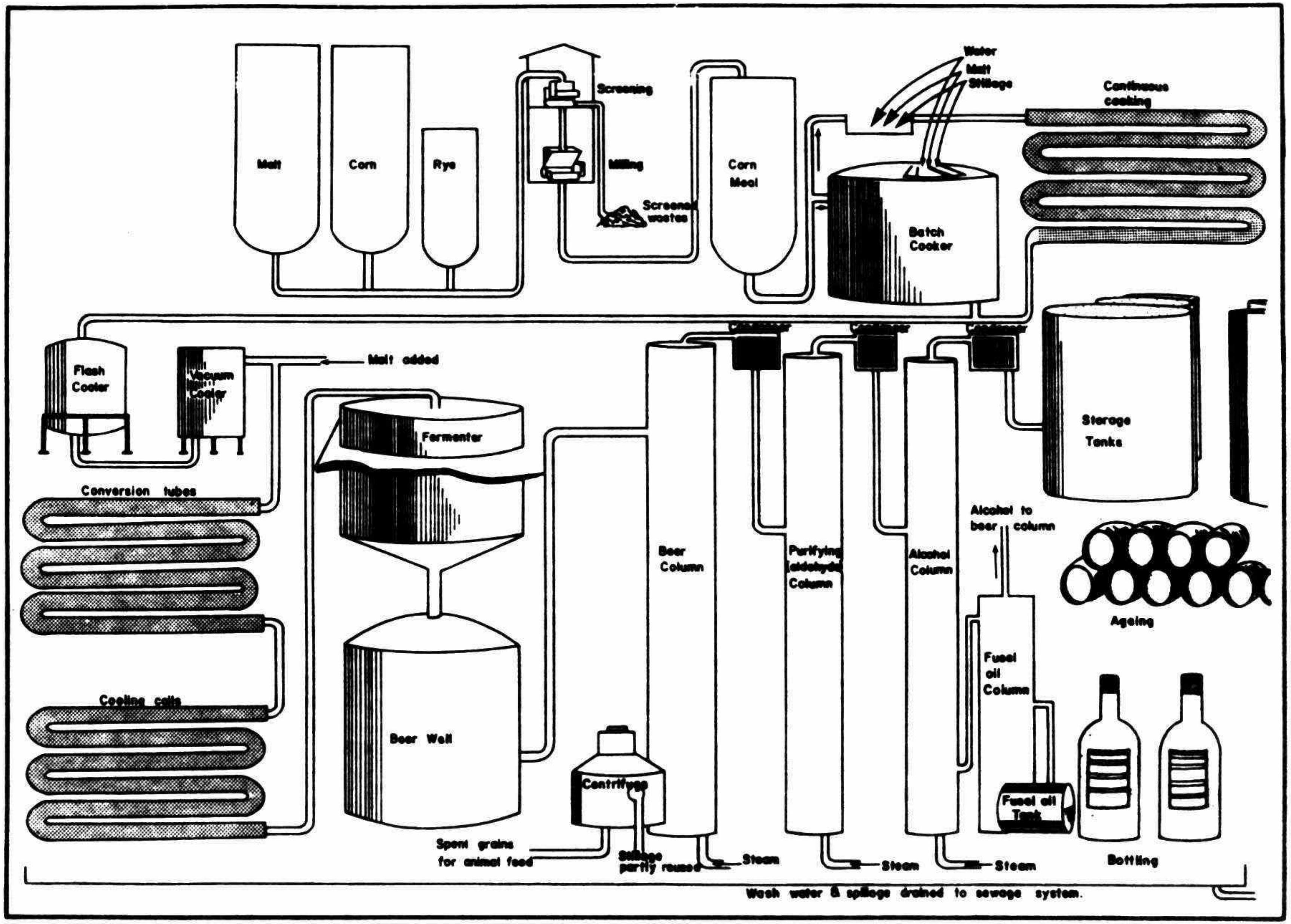


Figure 7-2
Distillery

the mash to continue boiling while it cools. It also releases volatile components and usually a carry-over of solids occurs. If a vacuum pump or condenser is used, a low volume waste is generated. If a barometric condenser is used, a large volume of low strength waste results, which is difficult to handle.

(2) Distilling

The mash cooler produces a large flow of uncontaminated cooling water; the fermenters also require cooling water. Slop from the beer still is further processed, leaving the distillation bottoms as a waste. These tails, or lutter water, can be separated in fractions as industrial solvents, or can be sent to another plant for separation. No matter what the procedure, a sewered waste results.

(3) Water Treatment

Regeneration of the de-ionizer produces acidic and alkaline wastes which must be treated, and depending on the boiler water treatment system, further wastes are usually generated.

(4) Boil-Outs

The most significant waste loading results from the weekly or twice-weekly boil-out, similar to that in a brewery. Several thousand gallons of approximately 3 percent caustic solution are boiled and passed through the process. This results in a batch waste with a high pH and a large organic content. The BOD loading produced is usually much greater than the total loading discharged on a normal operating day.

(5) By-Product Recovery

Apart from the process, an important operation is represented by the dry house, or recovery operation. This is an integral part of a conventional distillery, due to the high value of the recovered by-products.

Slop has been fed to cattle directly from the beer still, but this generally presents problems. A lot of water must be trucked, and due to the low solids content of the material, the cattle do not gain weight without an additional food source. In addition, this transfers a distillery waste problem to a cattle manure problem, which may be more difficult to control.

The standard practice is to screen the slop to separate the spent grains for drying in a rotary drier, then to pump the liquid to a multiple effect evaporator to be concentrated and dried in a drum drier. With the exception of the caustic boil-outs, the operation of the evaporator produces the critical organic waste.

In a simple evaporator, 1 pound of steam will theoretically evaporate 1 pound of water. In a multiple effect evaporator, such as a five effect (5 stages), 1 pound of steam will evaporate 5 pounds of water. A vacuum is applied to the final effect, resulting in a slightly lower vacuum in each of the preceding effects. This allows each of the effects from the beginning to operate at a slightly lower temperature. Steam from the boiler heats the first effect, and the condensate can be returned to the boiler. The water evaporated from the first effect (actually water and volatile components having a BOD of some 600 ppm) condenses in the coil of the second effect, and, since it is under a vacuum, must be pumped out of the heating coil. Similarly, water evaporated from the second effect condenses in the third effect, and so on. The water evaporated from the final effect is collected by the barometric condenser which is used to produce the vacuum on the evaporator.

Thus, the water added to the process through the cooker leaves by the evaporator condensates (except for the small amount in the distillation tails, a smaller amount in the product, and moisture losses from the driers).

(6) Equipment Leaks and Spills

In all industries, equipment leaks and spills are a major consideration. In distilleries, the dry house area is the most important because of the high organic content, or BOD, of the material being handled.

Waste Disposal Practices

For many years, disposal practices of the distilleries in Ontario have consisted of discharging wastes to municipal sanitary sewer systems and to natural watercourses.

Look at the process flow sheet. Contaminated wastes, distillation bottoms, miscellaneous wash water, and the condensates from the middle effects can be segregated for treatment in either a municipal or private treatment system.

The most key waste, boil-out solution, can be hauled away, neutralized and added to the contaminated wastes for treatment, or perhaps bled into the recovery plant.

To go one step further, uncontaminated cooling water, such as from the mash cooler, can be recycled through cooling towers. The need for treatment of the blow-down from this system would depend on the chemicals added to control corrosion and slime growths in the system. In the same way, the flow from the barometric condenser in the dry house can be recycled through cooling towers. However, this flow also picks up BOD from the final effect of the evaporator and the blow-down would require treatment for BOD removal.

Expected Loadings

Expected loadings appear to be about 0.3 pounds of BOD per bushel of raw material. Again, the waste flow that can be segregated for treatment is extremely variable, but 10 gallons per bushel seems reasonable.

Thus, a large distillery (10,000 bushels per day) could segregate up to 3,000 pounds of BOD in a flow of 100,000 gallons per day for treatment, and discharge several million gallons per day of cooling water to a storm sewer or natural watercourse.

WINERIES

Process and Sources of Wastes

Refer to the simplified flow sheet, Figure 7-3. Considering only grapes, there is no elaborate water treatment system since there is no added water in the product.

The grapes are tumbled to remove the stalks and foreign material, crushed, pressed, and then fermented. The remaining operations are clarifying the wine, aging, blending, and bottling. As in a distillery, bottling is a dry process.

Wash-up of equipment produces significant wastes. The only operation that could be considered as by-product recovery concerns the lees, or sediment, left in the bottom of the fermenter. This is trucked to a distillery for recovery of the alcohol which is returned to the winery for fortification (strengthening) of some types of wine.

One waste product is the pulp remaining after the juice has been removed. This is discharged from the press (or from the fermenter, since some wines are fermented "on the skins" or the skins are also added to the fermenters). This pulp is trucked away and usually ploughed into the ground in the vineyards. The rest of the process involves removing solids to leave the wine clear; the sediment is removed either in the form of filter cake or tank washings. Depending on the design of the filter, the filter cake can be trucked away for disposal or can be washed down the sewer.

Expected Loadings

A small plant would process 50 tons of grapes per day, producing some 180 gallons of wine per ton of grapes. Waste loadings are in the range of 4 pounds of BOD and 1 pound of suspended solids per ton of grapes processed. While the amount of water used and the concentration of the waste components varies considerably, depending on the cooling water systems and general procedures, 600 gallons of water per ton of grapes may be assumed to be average.

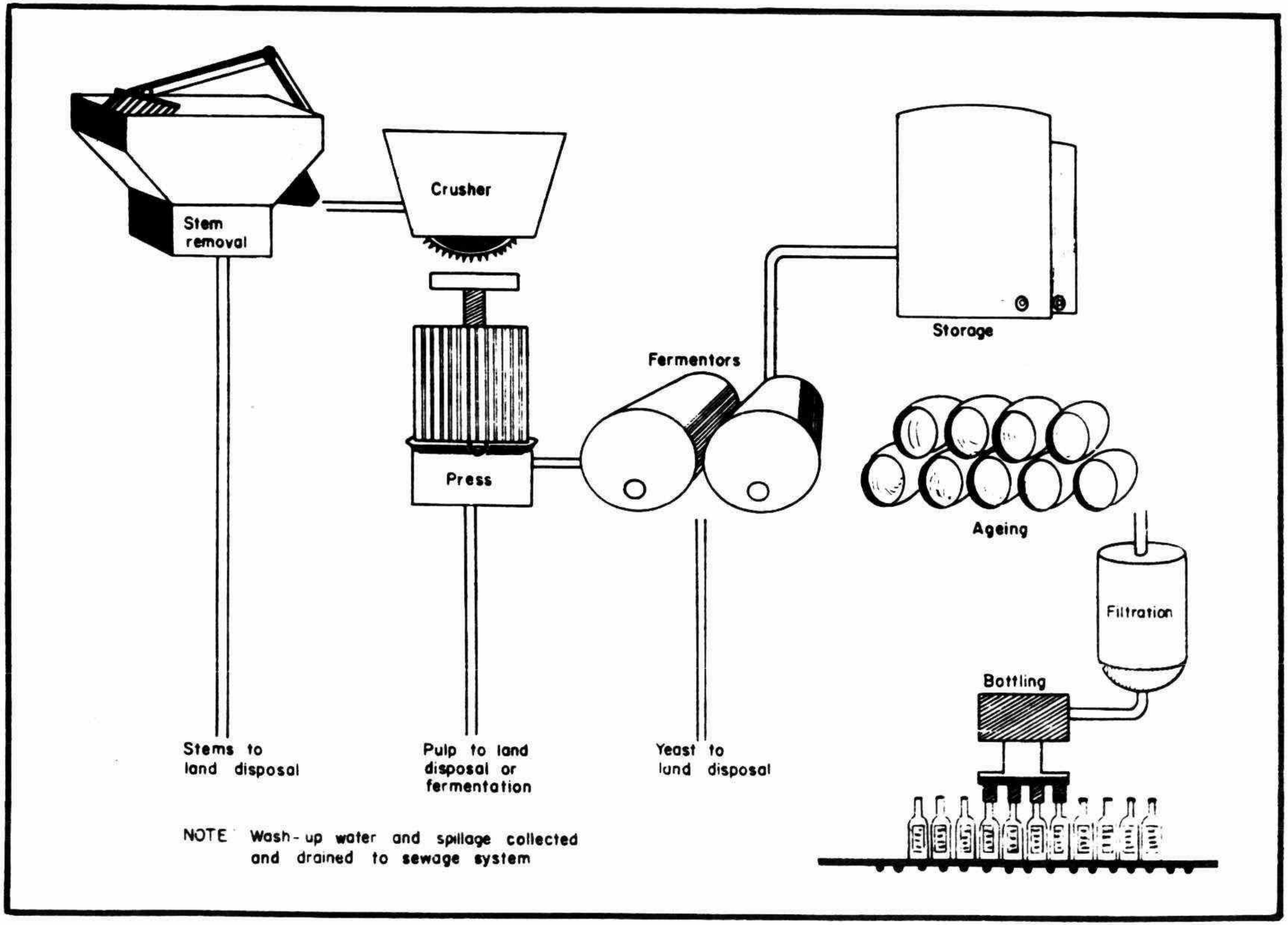


Figure 7-3
Flow Chart - Winery

Winery wastes have a low pH, lower than the 5.5 normally quoted in sewer use by-laws. In spite of this, there have been no severe corrosion problems, probably because the low pH is due to weak organic acids. If biological treatment is used for BOD removal, the organic acids are also removed and pH returns to a near neutral level.

Seasonal Operation

Wineries have a seasonal production schedule of approximately 8 weeks in the Fall. During the rest of the year, waste loadings are much reduced since the process involves only blending and bottling.

Waste Reduction

To reduce waste loadings from a winery:

> *First, as much of the raw material should go into the product as possible. This involves the pressing area; while most winery presses are reasonably efficient, older presses may lose a great deal of juice. Apple juice plants are more likely to be a problem in this regard. Another consideration is the efficient and complete draining of tanks and equipment before the wash-up. As with most food plants, the products being handled have an extremely high BOD; prevention of spills and leaking equipment is extremely important.*
>
> *Secondly, as much material as possible should be trucked away for disposal, so there is less to flush to the sewers. This involves efficient removal of grape pulp and land disposal of filter cake. Most filters used are designed for flushing of the filter cake to the sewers, but filters designed for dry cake disposal are available.*

Methods of Treatment

The seasonal nature (8 weeks in Fall) and high strength of winery wastes, suggests that spray irrigation is the most obvious and practicable method of waste disposal.

However, the Ontario wineries are located in urban areas where the necessary land for spray irrigation is unavailable.

With winery wastes, as is the case with breweries and distilleries, and also with most processing wastes, the organic loading (or BOD) is the main consideration. Thus, biological treatment is still the only practicable treatment method available. Biological treatment can be used to treat winery wastes on their own, not mixed with municipal wastes. The closest winery with such a system is in New York State, which uses aerated lagoons followed by polishing ponds to meet the State's trout stream criteria.

All of Ontario's wineries, with one exception, are connected to municipal systems and none have elaborate pretreatment systems. However, none appear to be causing severe problems at municipal sewage treatment plants.

SUMMARY

The operations in breweries, distilleries, and wineries result in considerable wastes. Investigations of individual plants may result in waste loading data somewhat different from that mentioned here. However, the process and the source of the individual wastes will indicate the areas where significant improvements can be realized.

This industry is reluctant to change its operating procedures. In spite of this, it is cooperative in its approach to waste control. There are several reasons for this. The industry has the money to do what it must do and, while "the art" is still involved in making alcoholic beverages, the plants are run by competent scientific personnel. They are operating processes similar to those at sewage treatment plants, and thus can readily understand the problems that may result if wastes are not adequately controlled. Finally, this industry is one that deals directly with the public in creating a demand for its products. To maintain its position in the market place, it guards closely its public image. The avoidance of adverse publicity which might arise over a pollution control problem is strong motivation for maintaining adequate control of wastes

CHAPTER VIII

VEGETABLE AND FRUIT PROCESSING (CANNING)

Introduction

There are some 150 establishments in Ontario registered with the Federal Government as plants processing fruits and vegetables and preparing them as canned commodities.

During the peak operating season, the active canneries in Ontario represent a total labour force in excess of 60,000 people. Canning is normally a seasonal operation lasting for approximately six months: from early May through to the first frost, usually at the end of October. The processing at these plants varies continuously and widely fluctuates with the type of produce, market demands, weather conditions, size of crops, etc. Canneries that operate year-round usually produce soups, pork and beans, macaroni products, etc., during the winter and spring period.

The canneries present a somewhat unique problem because they usually discharge large volumes of strong wastes only during the summer months. The volume and nature of the wastes vary considerably with each pack. Therefore, any treatment facilities provided to handle these wastes usually have to be very flexible in order to provide complete treatment. Because canneries produce food for human consumption, they are subject to strict requirements under the various health legislations. Absolute cleanliness if essential and this calls for the heavy use of water to keep all utensils, machines, tools and the product itself clean.

Process wastes from the canning industry cannot be discharged to a watercourse without treatment. They normally contain high concentrations of suspended solids, as well as soluble organic material that can exert a high BOD but they do not in themselves pose a hazard to public health since they are not toxic. The organic nature of the waste is most significant during the warmer weather when the dissolved oxygen content in a natural body of water is relatively low and the rate of decomposition of organic material is relatively high. The effects of an organic discharge to a body of water or to a watercourse are most severe in summer. Therefore, treatment of wastes prior to disposal is an absolute necessity.

Under the various government financing schemes more and more sewage plants are being built in smaller communities and municipalities. Many canneries in these areas will discharge their wastes to the sanitary sewers for treatment at these plants. Also, because of better transportation methods that are now available, more canneries are being built in towns rather than in the country, to take advantage of the municipal treatment facilities.

PROCESSING

Before proceeding with the type of problems that may be encountered from the indiscriminate discharge of canning wastes to the sanitary sewer, look at some of the internal operations associated with the canning of a product. Generally, the harvest arrives by truck directly from the farms for immediate processing, since prolonged storage may affect the quality of the product. From the unloading platforms, conveyors carry the produce into the plant. If the fruit or vegetable is of a fragile nature, it is normally dumped into a water flume to soften the fall. This water is usually recirculated and sewered only when it becomes too dirty, normally at the end of the operating day.

Washing and Initial Preparation

Once inside the plant, the produce receives a primary wash which may be in the form of a spray rinse or immersion into a running water rinse to remove mud or grit. In the case of corn, the produce is passed first through a cutter where the husks are removed. Wastes from the primary washing operation are normally low in BOD and high in suspended solids. This is especially the case when root vegetables such as potatoes, carrots, beets, etc., are processed.

After the primary wash, the produce goes through a number of preparatory stages to bring it to a state suitable for canning or freezing. A number of process wastes are produced during these stages. The nature of these wastes varies widely depending on the product and the number of operations required.

Peas and string beans, for example, require little processing other than washing and classifying. A brisk spray is usually sufficient to remove the loose dirt and cuttings from the produce before centrifuging and screening to grade the product. Large quantities of water are used as a carrying medium to transport peas from one stage to another. In general, when peas and wax beans are processed, large volumes of wastes are produced that are relatively low in BOD and suspended solids. In some cases, where the distance of transport is great, pumps used to convey the produce may crush it, releasing natural juices into the water. If this occurs, BOD concentrations may increase considerably.

Peaches, cherries and pears (fruits that have pits and cores), have to be opened to remove the inedible material. Prior to this, peaches and pears are passed through a caustic solution to remove the peel and then through a water spray to wash off the adhering chemical. Cherries, on the other hand, are passed immediately to a rotating drum where the pits are removed automatically. Whenever a product is broken during its preparation, there is usually a substantial loss of material to the process water resulting in an eventual discharge of strong wastes having high concentrations of BOD and suspended solids.

Potatoes are either peeled mechanically, or immersed into caustic solution to remove the outer covering. Rinse waters following this operation contain high concentrations of suspended solids, and in the case of lye peeling, have a high pH. Potatoes can be canned whole or may be further processed into potato chips or french fries. To produce chips, the potato is thinly sliced and then cooked. French fries can be frozen immediately after being washed, or can be pre-cooked and frozen in the partially cooked stage. Potato processing wastes contain high concentrations of BOD (starch) and suspended solids, but are normally deficient in nutrients. If lye peeling is used, the wastes also exhibit a high pH.

Tomatoes are usually processed into juice or canned whole. In the production of juice, the tomatoes are first passed through slashers and then through extruders to separate the solids from the liquid. The pulp is wasted (hopefully to a land disposal site and not to sewer), while the juice is blended, pasteurized, and finally canned. Whole tomatoes are prepared by hand on long tables where the core and peels are removed. Cans containing whole tomatoes are topped off with juice and sealed. Deformed or highly bruised tomatoes are rejected and passed on for juice production. Wastes from the tomato processing industry are discoloured, and high in BOD and suspended solids.

Pumpkin and corn processing produces the strongest waste discharge from the canning industry. In both cases, the product is not only broken but crushed. Since there is prolonged contact of the vegetable with the process water, there is a substantial transfer of material into the water phase. Dewatering of the corn after washing results in the discharge of a very strong waste. The cooking of pumpkins prior to pulping produces an effluent that is extremely potent. Although the processing of the above two vegetables does not produce large volumes of wastes, the wastes are extremely strong, and have high concentrations of suspended solids and BOD.

Cooking

After the cans have been filled and sealed, the contents are cooked by placing the cans into a pressure cooker. After cooking, the cans are cooled to lower the temperature for easier handling. In some cases, the cooling water is recirculated or re-used in other plant operations. However, in most instances, it is sewered after a single run. This waste stream is normally uncontaminated and suitable for discharge to a natural watercourse.

Blanching

Following initial preparation, the fruit or vegetable may be blanched. This involves partial cooking, either by brief immersion into scalding water, subjection to steam heat, or by simply setting on a hot steel belt. After blanching, the product is cooled, packaged, and quick frozen ready for distribution. The only wastes produced from the freezing of vegetables would be periodic dumps of blanch water, cooling water from the compressors on the freezing units, and general clean-up waters.

Clean-Up

As all these plants produce foods for human consumption, it is essential that all operations be clean. The machinery, floors, and utensils are therefore washed at the end of each processing day. The clean-up operations require copious amounts of water and last anywhere from three to six hours. During that period, wastes of variable strengths are discharged, being extremely potent at the start and tapering off towards the end of the clean-up period. The effluent contains not only organic wastes but also some alkaline cleaning solutions.

As mentioned previously, the wastes from this particular industry fluctuate considerably from pack to pack and in some cases even from day to day when the same product is being processed. The farming aspects have become very scientific in the last decade. Planting of the crop is planned with care to have the product ripen within a few days of a pre-arranged time to correspond to the predicted market demands and the scheduling of the cannery operations. Consequently, as all the product is ready for harvesting more or less at the same time, the cannery must work on a continuous basis to handle the incoming load. Of necessity, the operations are hurried and at times tend to become somewhat sloppy from the waste control point of view. On top of this, some of the workers in the lines are piece-work employees and consequently it is very difficult to apply in-plant control.

Because of the nature of the industry, it is difficult to provide an accurate relationship between the rates of production and the waste loadings discharged. If the product is cut or broken during the processing and the internal contents are transferred to the wash waters, the plant effluent is usually very potent with high concentrations of soluble organics that exert a high BOD. On the other hand, if the product is only washed, wastes of relatively low BOD are involved.

Sources of Pollutants

Significant pollutants in this industry arise from the following operations:

(1) washing;
(2) lye peeling;
(3) sorting, slicing, cutting, blending;
(4) processing;
(5) cooling of cans;
(6) plant clean-up; and
(7) box washing.

In general, the wastes may be divided into three broad categories:

(1) peas and wax beans processing wastes are high in volume but relatively low in suspended solids concentrations and exhibit a relatively low BOD.

(2) peach, carrot, tomato, strawberry, potato, and cherry processing wastes are of intermediate strength and volume.

(3) corn and pumpkin processing wastes are low in volume, but very potent, containing high concentrations of suspended solids and exhibiting an extremely high BOD.

The approximate relationship of the production rate to the expected strength and volume of wastes discharged is presented in Table A.

The following Figures 8-1 to 8-6 show the various flow charts pertaining to the processing of the various products.

MUNICIPAL TREATMENT OF PROCESS WASTES

There is a number of canneries throughout the Province that discharge wastes to a sanitary sewer for eventual treatment at a municipal sewage treatment plant. In a broad sense, because of their organic nature, cannery wastes have always been considered amenable to treatment. For this reason, this practice has been considered an excellent means of disposal. It does, however, have serious drawbacks because indiscriminate seasonal discharges of cannery wastes to a sanitary sewer may cause serious operational problems at the sewage treatment plant.

In general, municipal waste treatment systems fall into the three main categories: primary treatment, activated sludge, and lagoons. Each of these systems reacts differently to cannery wastes:

TABLE A

TYPICAL CANNING WASTES

PRODUCT	WASTE VOLUME (gal/case*)	BOD		SUSPENDED SOLIDS	
		(mg/l)	(lbs/case*)	(mg/l)	(lbs/case*)
Apples	29-46	1,500-5,500	.6-1.3	300-600	.10-.20
Cherries	14-46	700-2,100	.16-50	200-600	.05-0.14
Peaches	51-69	1,200-2,800	.69-1.20	450-750	.24-.34
Asparagus	80	16-100	.01-.07	30-180	.02-.12
Beans Green/Wax	30-51	160-600	.15-.67	60-150	.02-.04
Beets	31-80	1,600-7,600	1.00-2.00	740-2,200	.50-1.0
Carrots	36	520-3,000	.11-.67	1,800	.40
Corn	28-80	620-6,300	.17-1.50	300-4,000	.07-.95
Peas	16-86	380-4,700	.27-.63	270-400	.06-.20
Potatoes	-	200-2,900	-	990-1,180	-
Pumpkin	23-57	1,500-6,880	.72-1.31	785-1,960	.38
Tomatoes	3-114	180-4,000	.11-.17	140-2,000	.06-.13

*A case contains 24 cans of a size in which the produce is most commonly canned.

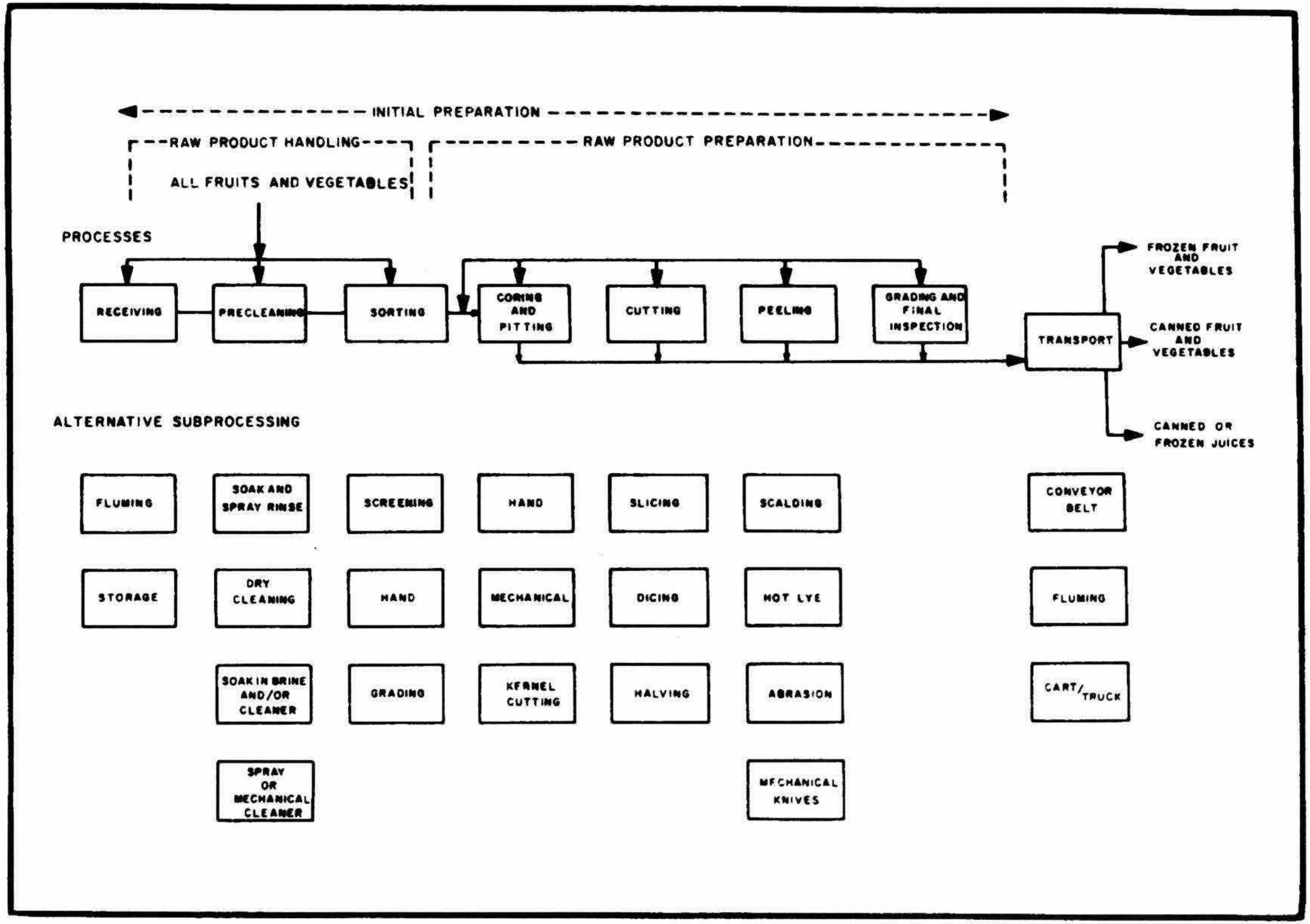


Figure 8-1
Flow Chart - Fruit and Vegetable (Initial Processing)

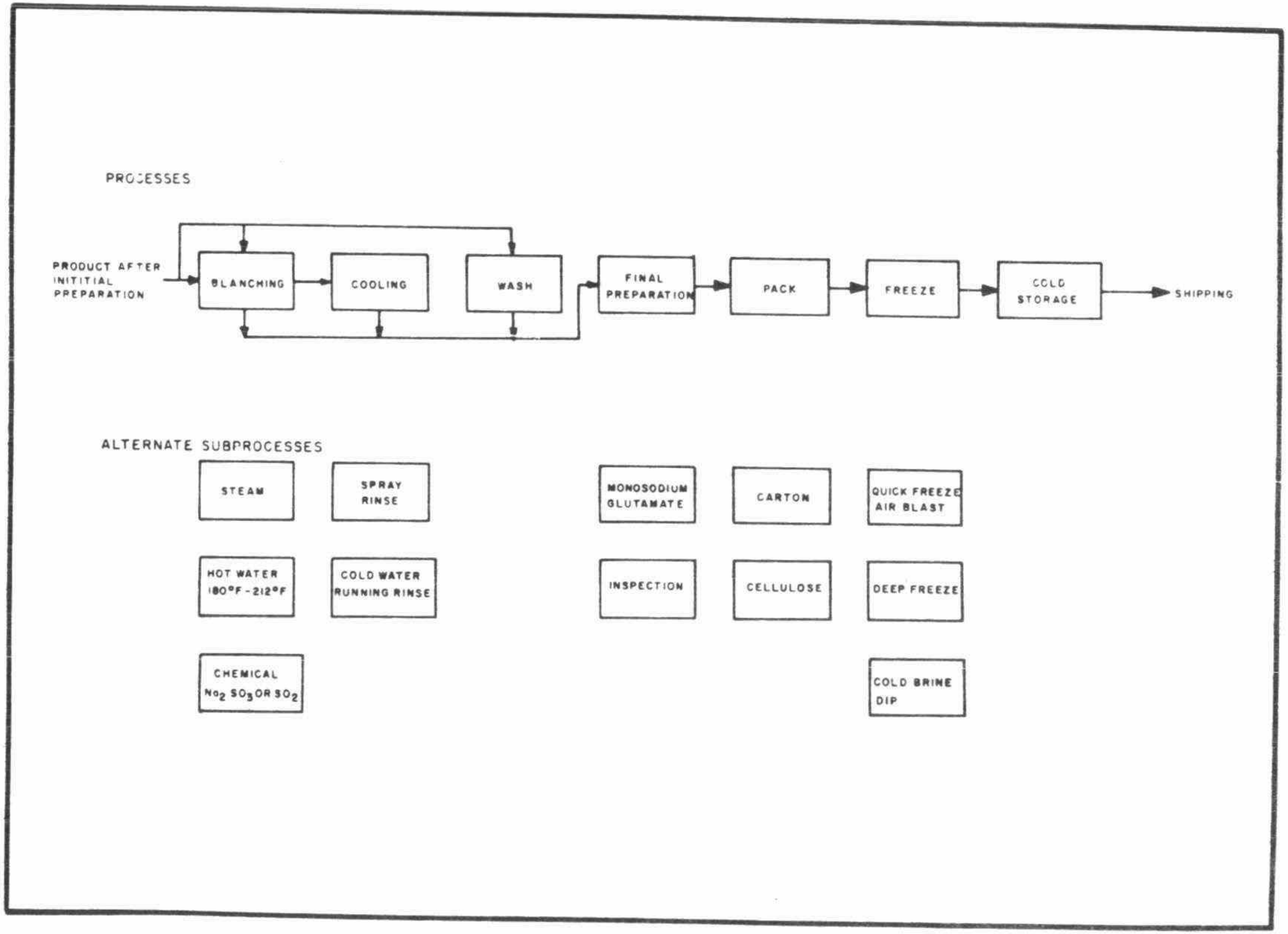


Figure 8-2
Flow Chart - Frozen Fruit and Vegetables

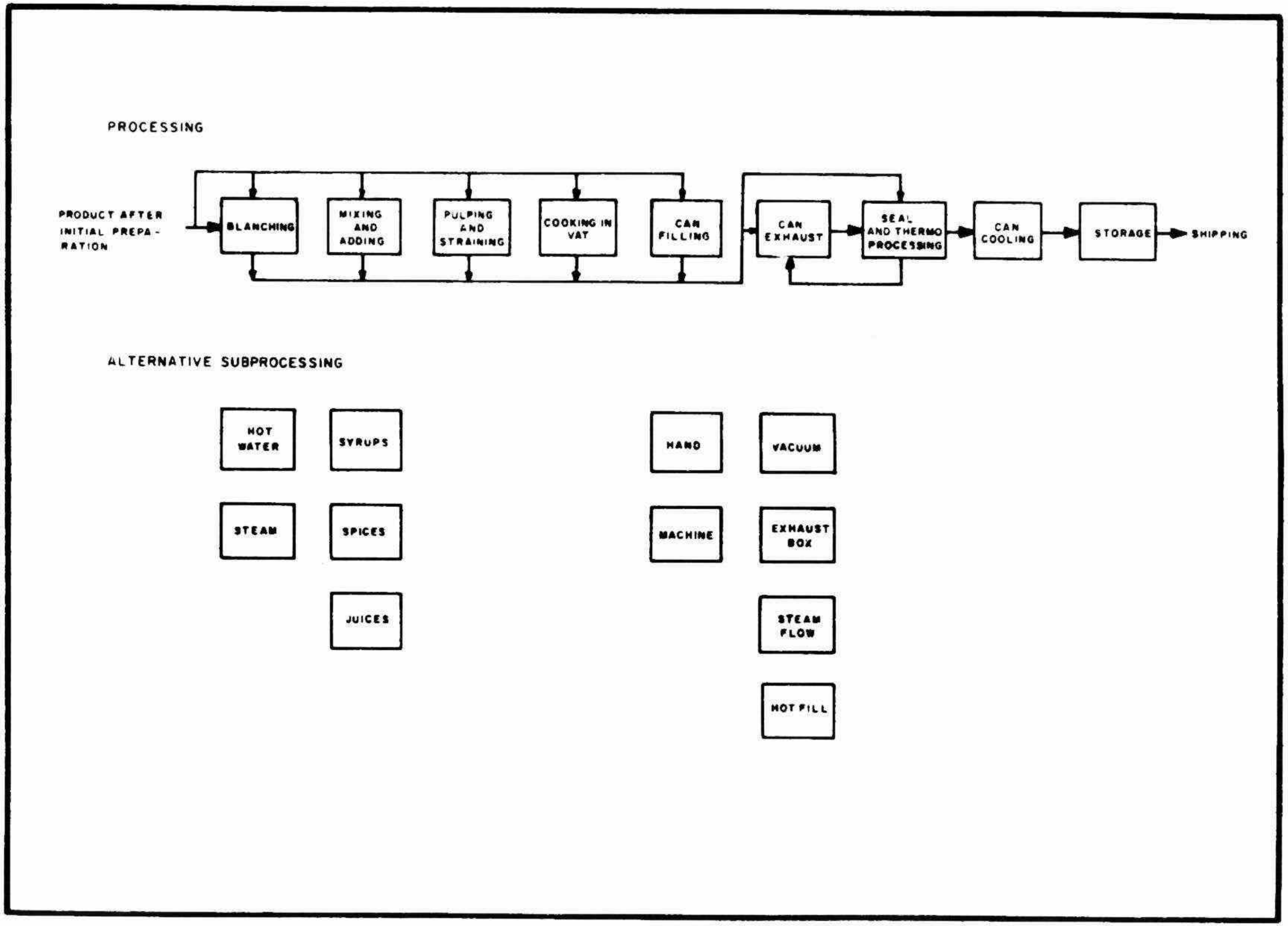


Figure 8-3
Flow Chart - Canned Fruit and Vegetables

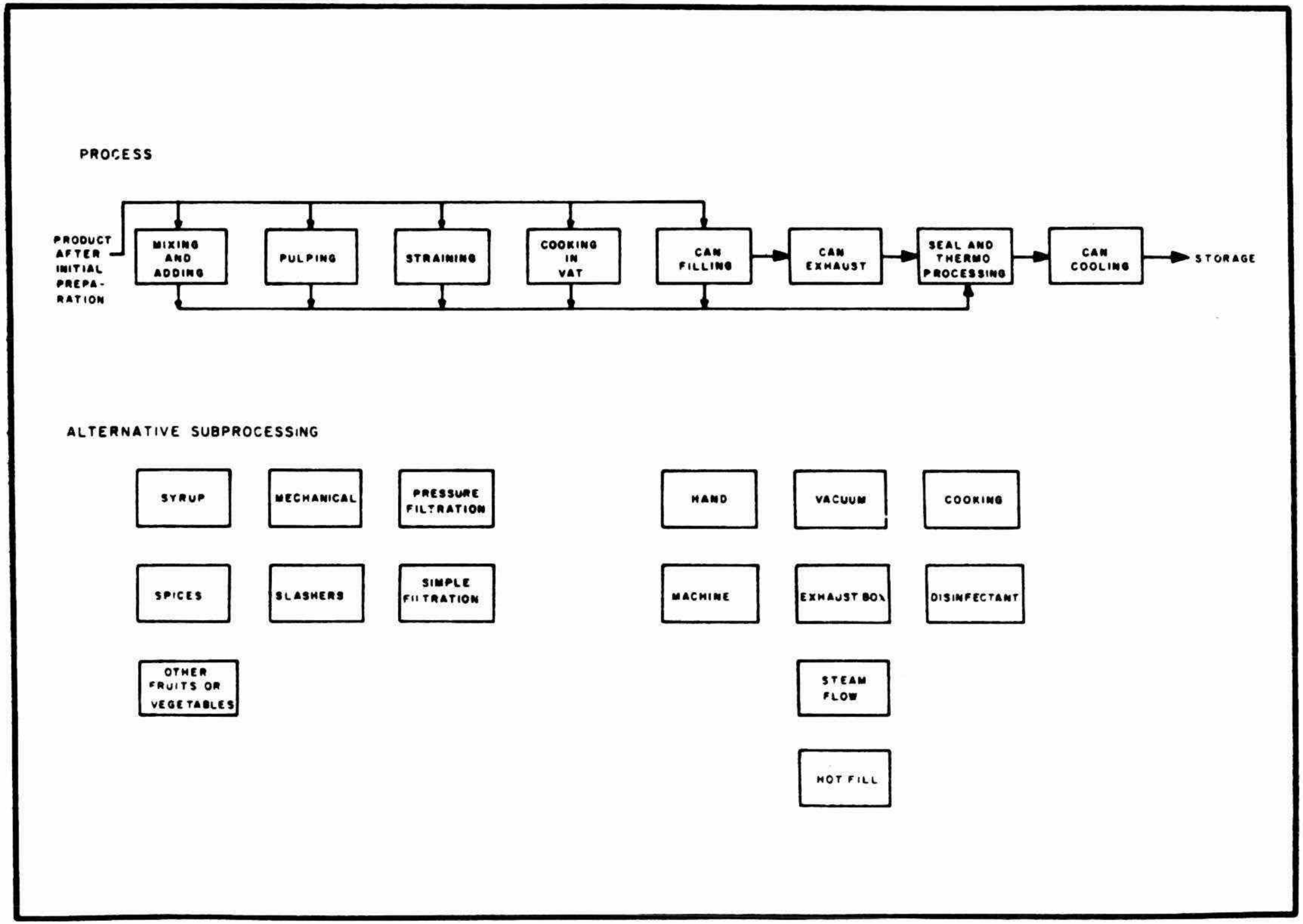


Figure 8-4
Flow Chart - Canned and Frozen Fruit/Vegetable Juices

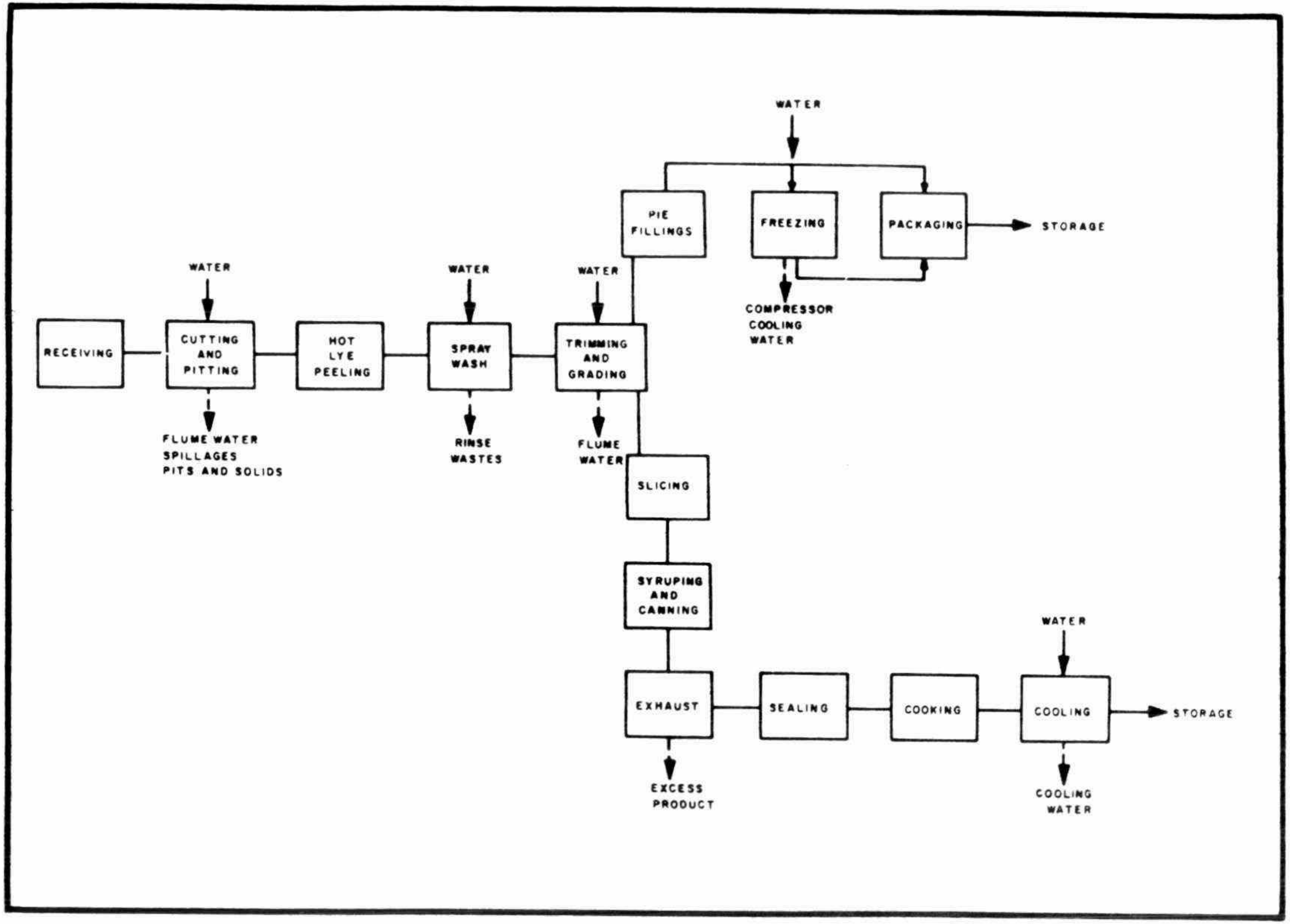


Figure 8-5
Flow Chart - Typical Peach Cannery Process

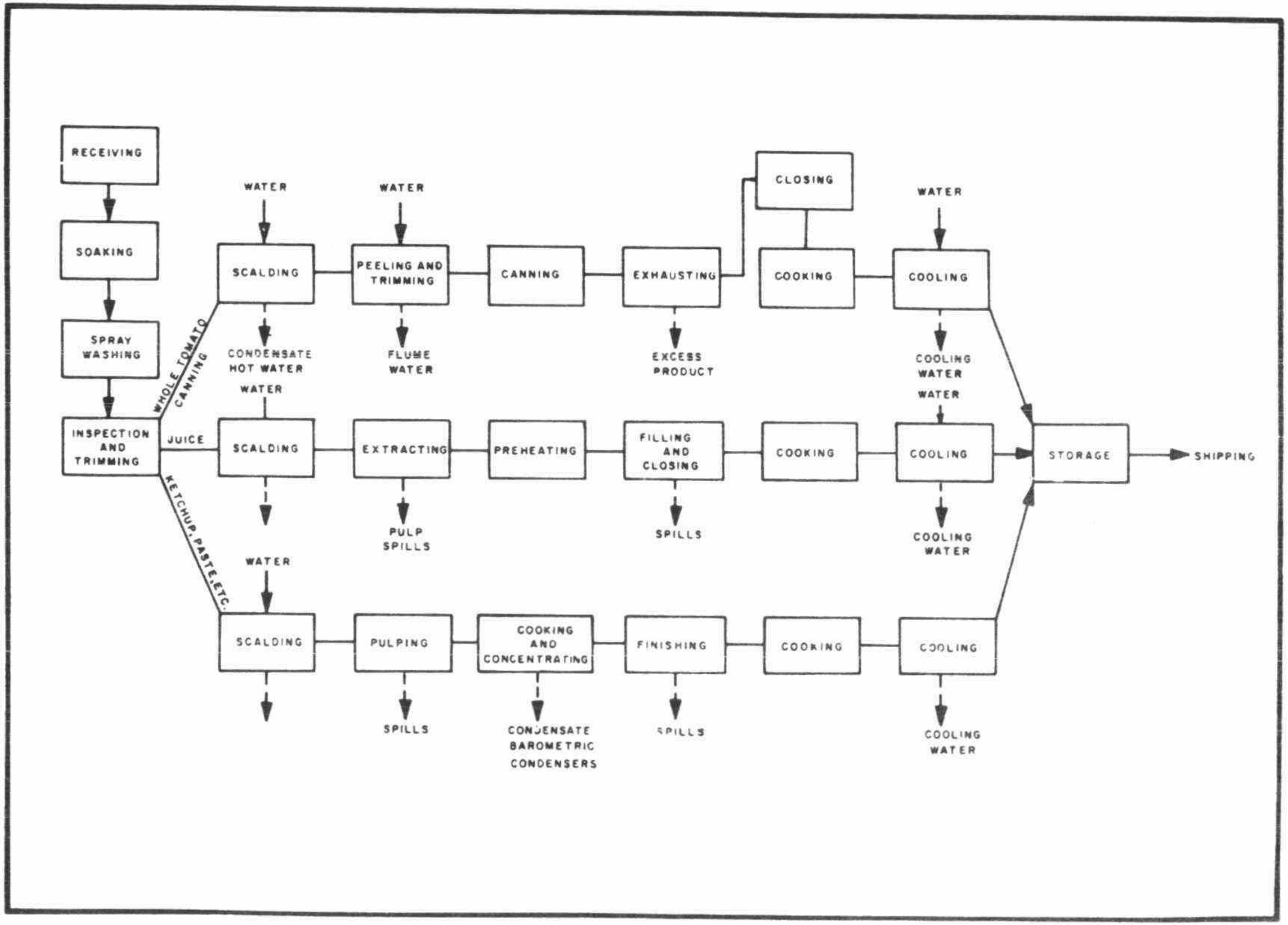


Figure 8-6
Typical Tomato Cannery

(1) Primary Treatment Plants

In primary treatment plants, some of the suspended solids and part of the BOD are removed from the wastes by sedimentation only.

In general, cannery wastes receive minimum treatment at a primary sewage treatment plant. Most of the entrained solids are of a fibrous nature and consequently do not settle out very readily. A major portion of the BOD is in a soluble form and very little of this is removed by simple sedimentation. If unscreened cannery wastes are discharged to a primary sewage treatment plant, only 50 percent of the suspended material is removed during treatment. If proper screening is carried out at the cannery, the above figure may drop to about 30 percent.

Unless the cannery is located in a built-up residential area, it may be more practical to provide primary treatment on site. This would remove a significant hydraulic loading from the municipal plant and result in better treatment of the sanitary wastes. If the municipal primary plant is later to be expanded to include secondary treatment, the treatment facilities at the industry could provide excellent pre-treatment and good equalization of wastes to permit the discharge of the process wastes to the sanitary sewer.

(2) Secondary Treatment Plant (Activated Sludge)

Cannery wastes can exert severe shock loads on biological treatment plants particularly the activated sludge process. Poor treatment efficiencies may result and effluents of unacceptable quality will be discharged until proper operations are restored.

It is difficult to acclimatize an activated sludge plant to cannery wastes because the waste volume and quality varies considerably from day to day as well as from pack to pack. In some cases, because of the strength of the process effluents, the waste loading from the cannery may equal or exceed the municipal contribution. If the municipal facilities do not have any reserve capacity, the treatment plant will become severely overloaded and produce a poor quality effluent. Cannery wastes may also be nutrient deficient. In these cases, nutrients (in the form of nitrogen and/or phosphorus) would have to be added at the industry or at the treatment plant when cannery wastes are being treated. Under these conditions, special agreements between the cannery and the municipality will be required.

Before cannery wastes can be accepted at an activated sludge plant, some form of pre-treatment at the industry is required. Pre-treatment normally consists of wastewater segregation, screening, equalization, and in some cases, aeration. The clean wastes (cooling waters) should be separated from the process wastes for direct discharge to a watercourse or storm sewers. This will reduce the hydraulic loading on the sewage treatment plant.

Screens are used to remove the coarse solids from the effluent to decrease the suspended solids loadings and some BOD. Screening is not a simple process and the screening facilities should be designed to suit the wastes.

Equalization of wastes is necessary to eliminate shock load effects on the activated sludge system. Retention facilities must be provided at the industry to hold the wastes for about 4-8 hours and the wastes are bled into the sewer at a controlled rate over a prolonged period of time. The retention basin allows mixing of wastes of various strengths (e.g., wash down wastes and process wastes), hence, the discharge of a more consistent effluent to the sewer. The cannery wastes are further diluted by the sanitary waste in the sewer which lessens the impact on the sewage plant operations.

In cases where the municipal facilities are definitely too small to handle the cannery wastes, the industry will be required to construct more complex pre-treatment facilities (e.g., biological treatment) to reduce its effluent BOD before the effluent is discharged to the municipal facilities for final polishing.

(3) Municipal Lagoons

In the smaller outlying areas of Ontario, stabilization lagoons are used to treat sanitary wastes. Although lagoons tend to absorb shock loads better than activated sludge plants, they are still vulnerable to high waste loading from canneries. The treatment efficiencies may drop considerably during the canning season if the waste *loadings discharged to the lagoon exceed the design criteria. Under such conditions, there will be insufficient oxygen in the heavily overloaded portions of the lagoon which may turn septic. This could result in the emission of obnoxious odours. Odours can be a problem during the ice break-up in the spring as a result of low biological activity during the winter.*

To overcome septic conditions, additional oxygen may be provided artificially through the addition of a nitrate. This should only be considered as a temporary solution. Aeration facilities could be installed and operated during the canning season to handle the surplus waste load. During the remainder of the year, the lagoon may have sufficient capacity to treat the sanitary wastes without aeration.

The capacity of the lagoon can be increased by constructing additional cells to handle the waste loading from the cannery. In the case where the waste loading from the cannery greatly exceeds the waste loading from the municipality, this type of expansion may be impractical. Unless there is a suitable cost-sharing agreement between the industry and municipality, the cannery must resort to private treatment.

PRIVATE TREATMENT

(1) Land Disposal

Some canneries use land disposal to treat their wastewaters:

(a) Spray Irrigation

Spray irrigation, the most common means of land disposal, is an adaptation of the artificial watering of crops by a portable sprinkler system. This system is attractive because of low operating costs, elimination of odour problems, and possible irrigation of edible crops. There are, however, a number of important design criteria that have to be met to make the system effective.

The wastes must be screened prior to spray irrigation to prevent blockage of the spray nozzles. Fine screening is usually sufficient for a trouble-free operation. A reservoir, large enough to maintain continuous pumping and yet small enough to prevent the wastes from becoming septic, must be provided.

The land is the single most important criterion. The soil characteristics and cover crop dictate the rate of application and hence the number of acres required to handle the wastes from a particular cannery. The soil characteristics vary from excellent (sandy loam), to poor (predominantly clay). A good cover crop is essential to increase the rate of absorption, evaporation, and transpiration, and to prevent the erosion and clarification of the soil. With a good system, three to four inches of wastes per acre per day can be sprayed with application rates not exceeding 0.4 to 0.6 inches per acre per hour. An area sprayed at this rate may be resprayed after about 4 to 6 days.

The system can be easily upset if the optimum rate of application is exceeded. If the nozzles are not relocated and land is over-sprayed or saturated with rain, pools of wastes may form. Obnoxious odours resulting from organic decomposition may become a public nuisance. If the land is sloped, over-application results in heavy runoff with surface drainage to a watercourse. All of these problems can be overcome by the acquisition of more land to increase the spraying area and to reduce the volume of wastes applied per acre. The drainage or runoff can be collected for respraying under more suitable weather conditions or for discharge to a sanitary sewer for final polishing at a municipal sewage treatment plant.

Spray irrigation is most convenient for the smaller or medium sized canneries located in rural areas. Once the waste volume approaches 200,000 to 300,000 gallons per day, the cost of land becomes the critical and over-riding factor making other means of treatment more economical.

(b) Spreading

Another means of land disposal is simply hauling and spreading the wastes on land. Canneries using this means of disposal tend to be small. Because smaller plants have relatively short operating periods, few problems are encountered.

Normally, the wastes are stored at the plant and then transported to the fields by tank truck. Spreaders are used to apply the wastes uniformly on the land and to prevent the formation of pools. This is an excellent means of disposal where sufficient land is available because it provides for complete treatment without any discharge to a watercourse.

The only danger in this method of disposal is over-application. Long-standing pools may form, turn septic from organic decomposition and emit obnoxious odours. Also, the fields may become muddy in spots and be impassable to vehicles, preventing further application of waste. For more efficient use of land, the area can be ploughed after the wastes have been applied. If this is not an immediate solution to the problem, additional land must be acquired.

(c) Ridge and Furrow

The last means of land disposal is ridge and furrow. A plough is used to run furrows approximately 3 feet deep and 3 feet wide on the land. This utilizes the topography so that wastes introduced at one end of the furrow can flow by gravity to the other end. Wastes are simply discharged into a series of such furrows and allowed to seep into the ground. This is a good means of disposal where smaller volumes of wastes must be disposed of and where the ground is sandy and porous enough to permit good percolation. Again, these systems suffer from hydraulic overloading and from soil classification which reduces infiltration rates.

(2) Lagoons

A number of smaller canneries in the Province use lagoons as total retention basins for storing all wastes produced during winter operations. In spring, the contents of the lagoon are emptied to a watercourse at a controlled rate to be diluted by the spring runoff. On occasion, the wastes are spray irrigated in early spring or summer to empty the lagoon and prepare it for the next operating season.

This "fill-and-draw" type of system works well, provided the cannery is not located in a highly populated area. In winter when there is an ice cover insufficient oxygen is transferred to the water and the wastes are subjected to anaerobic decomposition. In spring, summer and fall, treatment takes place by aerobic decomposition. Anaerobic conditions during the winter months are often the cause of odours during the spring break-up. Even though this condition normally lasts only for a few days, it may become a serious public nuisance.

Odour problems may be overcome by the use of masking agents during the ice break-up, or by aerating the lagoon during the winter to keep septic conditions to a minimum.

(3) Biological Treatment

Finally, the industry can install some form of biological treatment using mechanical aeration. Activated sludge plants, oxidation ditches, and aerated lagoons are all in use. It is possible to have BOD removal in the order of 90 percent and to produce an effluent that can be disposed of directly to a watercourse. These systems are complex, expensive to build and operate, and consequently are normally only found at the larger canning establishments.

CHAPTER IX

DAIRY PROCESSING

Introduction

Dairy processing includes industries using milk as the raw material and converting it to products such as cheese, butter, whole milk, buttermilk, powdered milk, ice cream, etc.

The dairy processing industry represents a viable and very necessary segment of our economy. Products such as milk, cheese and butter belong to one of the basic food groups necessary to a healthy diet. The industry, in general, has grown from small one-man rural operations to massive complexes. A network of farmer cooperatives, private businesses, nationwide store chains, etc., now bring the product to market.

In the past, numerous small plants were scattered around the rural community to produce a single product, largely to satisfy local demands. A manufacturing plant would produce butter as the main product and discard such by-products as skim milk and buttermilk. This was wasteful and became uneconomical as larger establishments produced a variety of products and sold them at lower prices. Modern transportation became available; whole milk and the final product could be transported greater distances to and from the rural communities. Smaller plants were unable to compete and closed down.

To centralize operations, larger milk producing plants are now located in municipalities where a ready labour market is available. Their wastes are discharged to sanitary sewers for ultimate treatment at the municipal sewage treatment plants. These waste discharges can affect the operation of a sewage treatment plant.

Creameries and condenseries are often together to allow use of cream and skim milk by-products in one location. Similarly, ice cream, fluid milk, and cottage cheese plants are combined for the most efficient utilization of whole milk.

Process Operations and Sources of Wastes

(1) Butter Manufacturing

Raw milk (unpasteurized) is delivered to creameries in tank trucks (or in ten-gallon cans at the smaller operations) where it is stored in refrigerated tanks before use. The raw milk is passed through a heater to bring the temperature up to about 90°F. It is then centrifuged to separate the cream which normally has a butter fat content of 30 percent to 40 percent. The cream is stored separately while the skim milk is used as a by-product for conversion into powdered milk, cheese, ice cream, etc.

The cream is cooled. Depending on the size of the operation, it is pasteurized in continuous flow pasteurization units (larger plants) or batch pasteurization units (smaller plants) by heating to 165°-175°F for 20 minutes. The cream is cooled a second time and sent to the churning units where butter is separated from buttermilk at a temperature of about 45°F. The butter is "worked" to the desired consistency and sent to packaging. The by-product buttermilk from the churning process is sent to waste or passed on for further processing. Figure 9-1 shows the basic process.

(2) Condensing and Drying

Milk, and by-products such as skim milk, buttermilk, whey, etc., are received in tank cars at large plants and in cans at the smaller plants. They are stored in refrigerated tanks prior to use. A centrifuge separates cream from whole milk for ice cream manufacturing. The skim milk is pasteurized and sent to the evaporators. The milk is evaporated under vacuum to prevent burning or damage due to excessive heat. Smaller plants use "batch" boilers while larger plants use multiple effect evaporators to reduce operating costs.

A 15 percent reduction of the water produces a condensed milk which can be sold in the condensed form or spray dried into milk powder. Spray drying consists of spraying the concentrated milk through heated air where the remaining water is removed. Condensed milk is cooled, stored, canned and shipped for marketing. Powdered milk is packaged in small bags or barrels depending on its

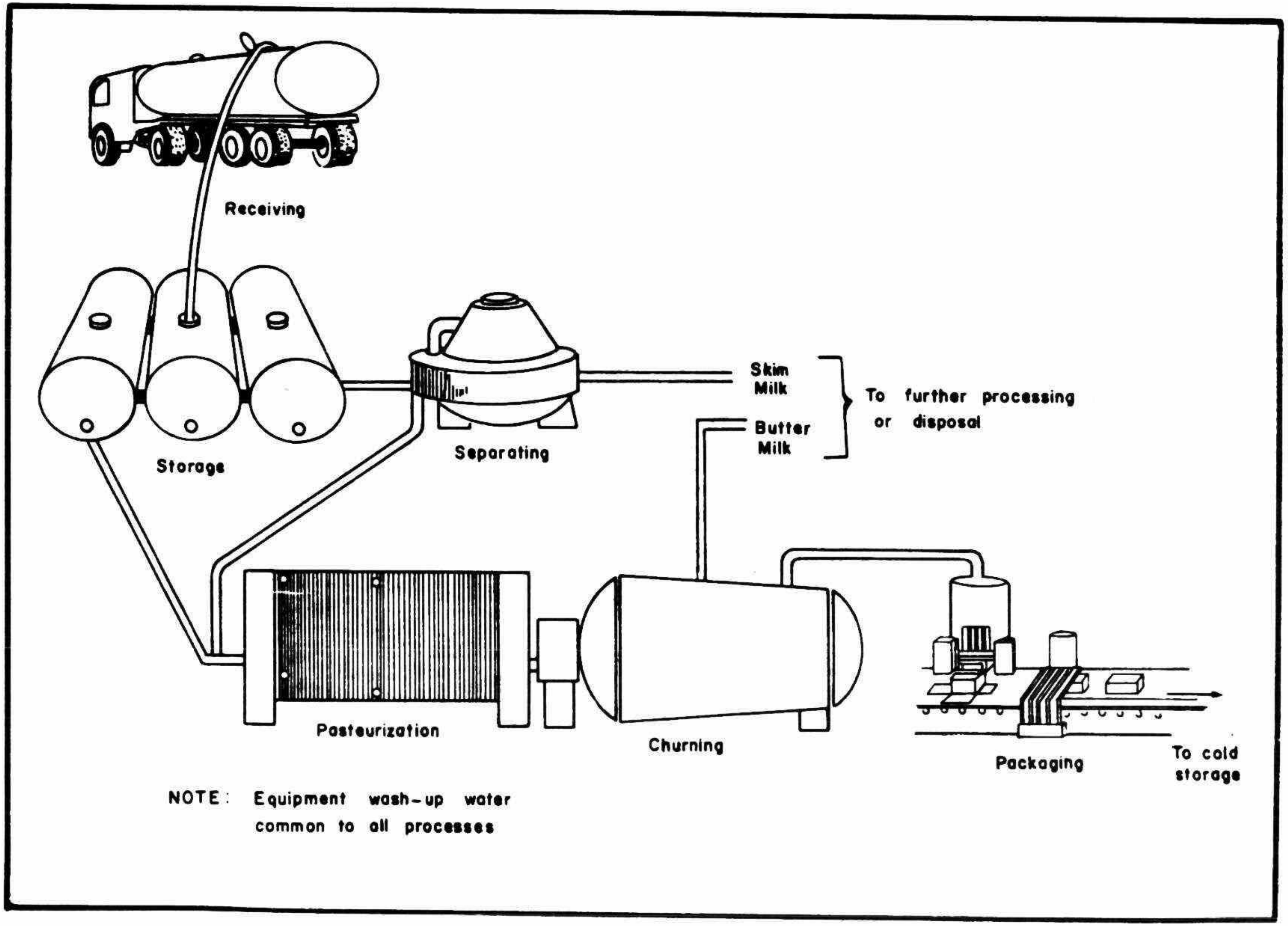


Figure 9-1
Flow Chart - Creamery Butter

ultimate use.

The most significant sources of waste are (1) spills and leakages associated with milk handling and (2) washdown water from equipment cleaning. Product spills may contribute high BOD loadings. Wash water contains soaps, chemicals, detergents, and some milk product, all of which create a heavy load on a sewage treatment plant.

A considerable amount of cooling water is utilized by the numerous heating and cooling operations. There is normally no direct contact of the cooling water with the product, so this water can be disposed of directly to a watercourse or storm sewer. In the evaporation step, the boiler vacuum is usually maintained by a barometric leg condenser. Normally the cooling water is clean; however, upsets in the boiler which cause the unit to "burp" can transfer some material into the water stream and cause contamination. The arrangement of pumps on the barometric leg condenser should permit the discharge of clean water to the storm sewer, and the discharge of contaminated water to the municipal system during upset conditions. Figure 9-2 shows the basic processes.

(3) Cheese Manufacturing

In contrast to the butter industry, the cheese industry has grown rapidly and is expected to continue growing. In the manufacture of cheese, a potent waste - whey - is produced, which cannot be readily converted to an economically useful by-product, and which can create a serious waste disposal problem.

Whole milk and skim milk are received at the plant in tank cars and stored in refrigerated tanks until ready for use. If low fat cheeses are made, the whole milk is heated and centrifuged to remove cream. This is a readily marketable by-product. The milk is pasteurized in batch or continuous flow pasteurization units, cooled and pumped to cheese vats. In the vats, the milk is innoculated with bacteria. The bacteria react with the milk to form curds and whey. The curds (solids) are separated from the whey (liquid) for production into cheese. The whey becomes the by-product, either sent to waste or converted to some usable form. The curds are rinsed and the (rinse) water is sent to waste. After rinsing, the curds are pressed and placed into a controlled environment to permit "aging". The maturing period

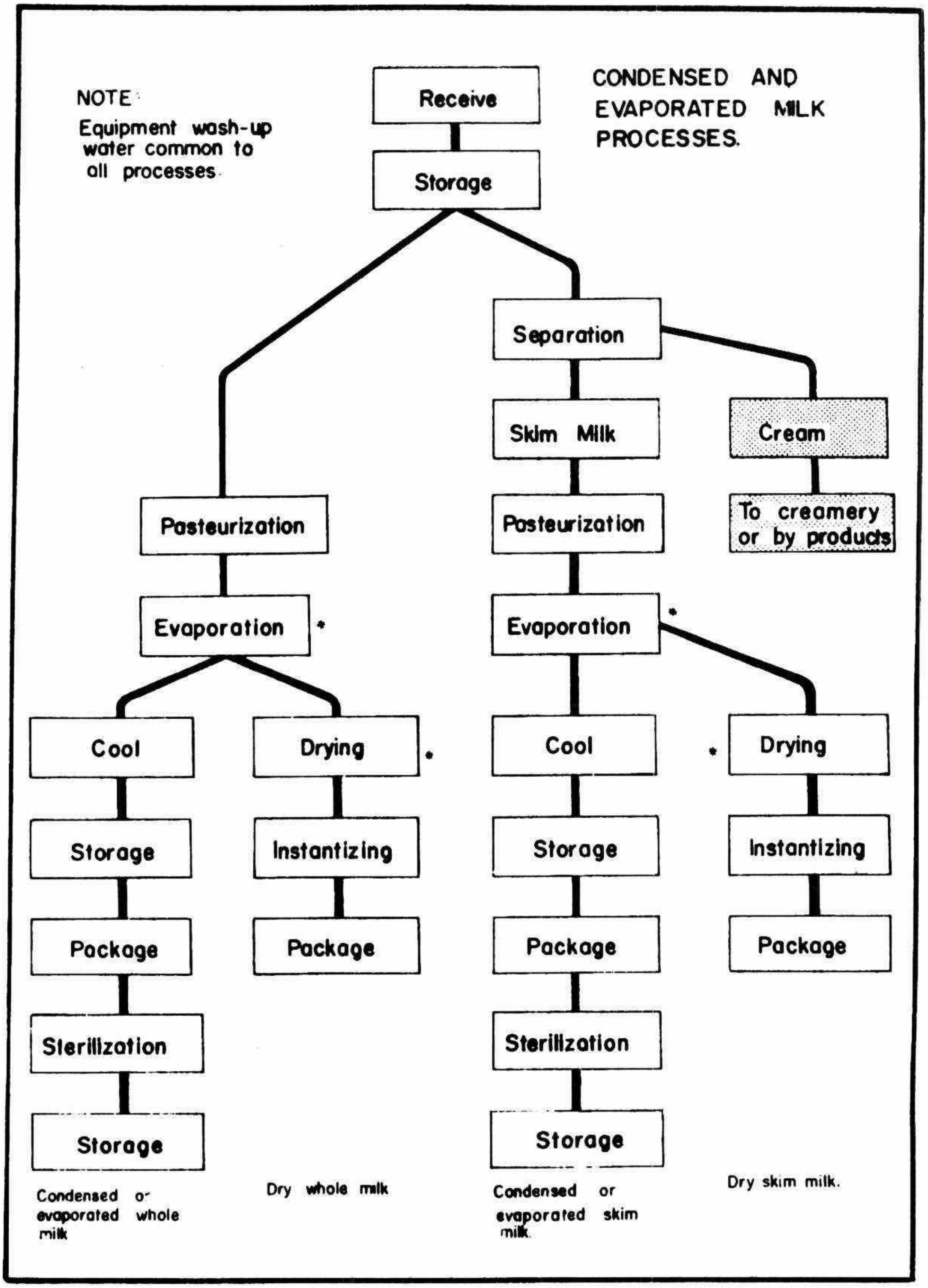


Figure 9-2
Flow Chart - Condensed and Evaporated Milk

lasts anywhere from days to months depending upon the variety of cheese produced. The final product is packaged or blended into a cheese by-product. A flow sheet of a typical cheese operation is shown in Figure 9-3.

Refrigeration and cooling after pasteurization requires a great deal of water. This water is normally never in contact with the product and can be discharged directly to a storm sewer or natural watercourse. The critical waste produced is the whey. Roughly, for every 100 pounds of milk used in cheese production, about 90 pounds becomes whey and 10 pounds becomes cheese. Whey can be dried to produce a usable by-product, but in most cheese factories the volume produced is too small to support an evaporation system. The whey which is usually discarded as waste has a BOD concentration in the order of 3.2 percent and has a high protein and acid content. Rinse and wash water used to wash the curds also contains some whey and therefore has a corresponding high BOD and suspended solids concentration.

Other sources of wastes are spillages associated with milk handling and equipment wash waters. These wastes are not as difficult to handle as whey, but they still contain high concentrations of BOD. They require some degree of treatment prior to discharge to a watercourse.

(4) Ice Cream and Frozen Desserts

The ice cream and frozen dessert industry has grown steadily and is expected to continue to do so. Since these plants reflect the population patterns, the larger plants are located in urban municipalities. Modern transportation methods permit distribution of products over a wide area. Figure 9-4 shows the basic manufacturing processes.

Raw milk is received at the plant in tank trucks and is sent to a refrigerated tank for storage until use. Ingredients such as stabilizers, emulsifiers, sugar, etc., are blended with the milk according to the formula of the product. The mixture is pasteurized and homogenized. Homogenization mixes and breaks-up the fat particles so that they remain in suspension. The mixture is cooled and sent to storage. From storage, the material passes through a further processing operation where nuts, fruits, and flavours are blended in to make the finished product. This is frozen to make the ice cream and/or frozen dessert.

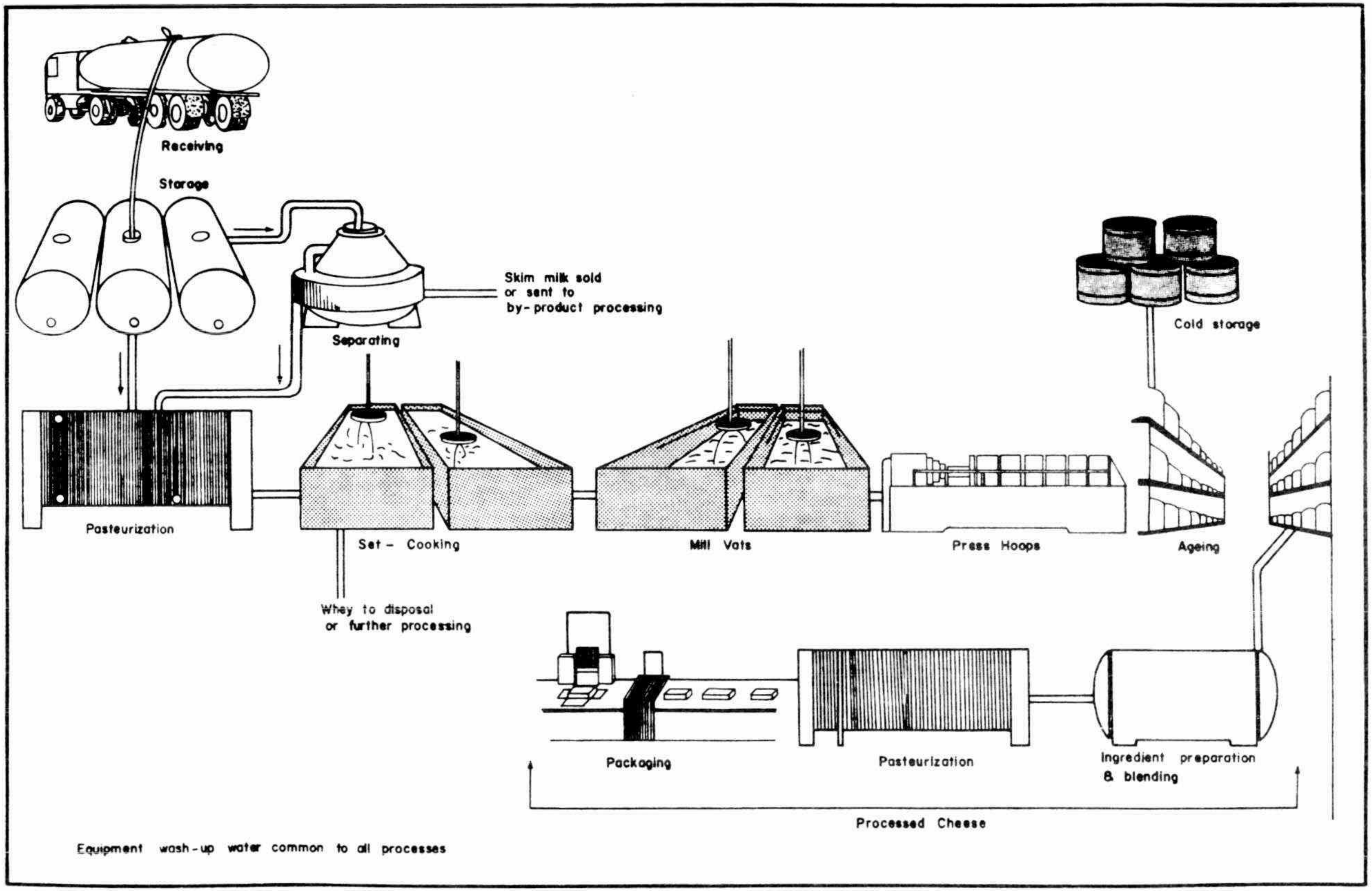
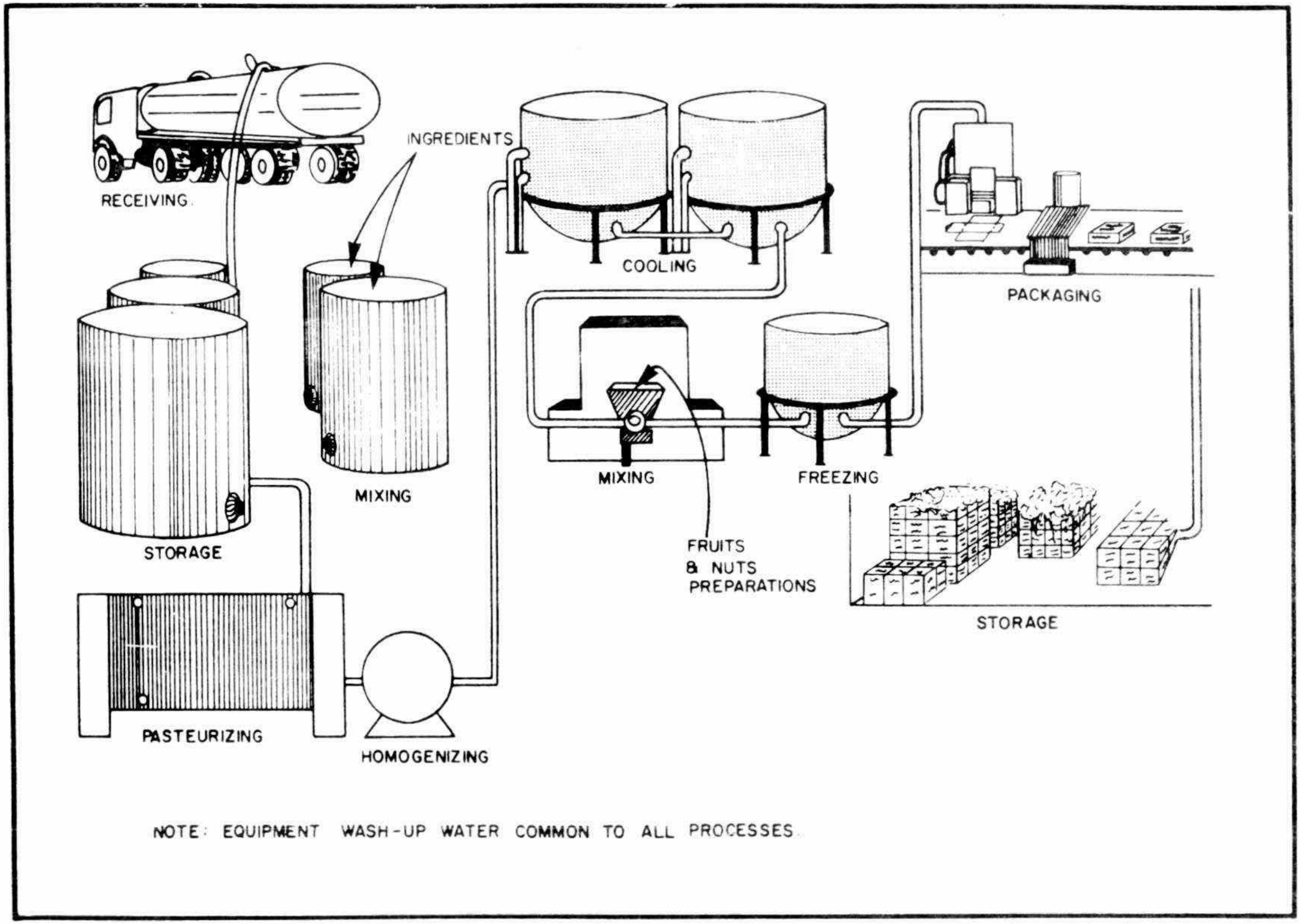


Figure 9-3
Flow Chart - Cheese



NOTE: EQUIPMENT WASH-UP WATER COMMON TO ALL PROCESSES.

Figure 9-4
Flow Chart - Ice Cream and Frozen Desserts

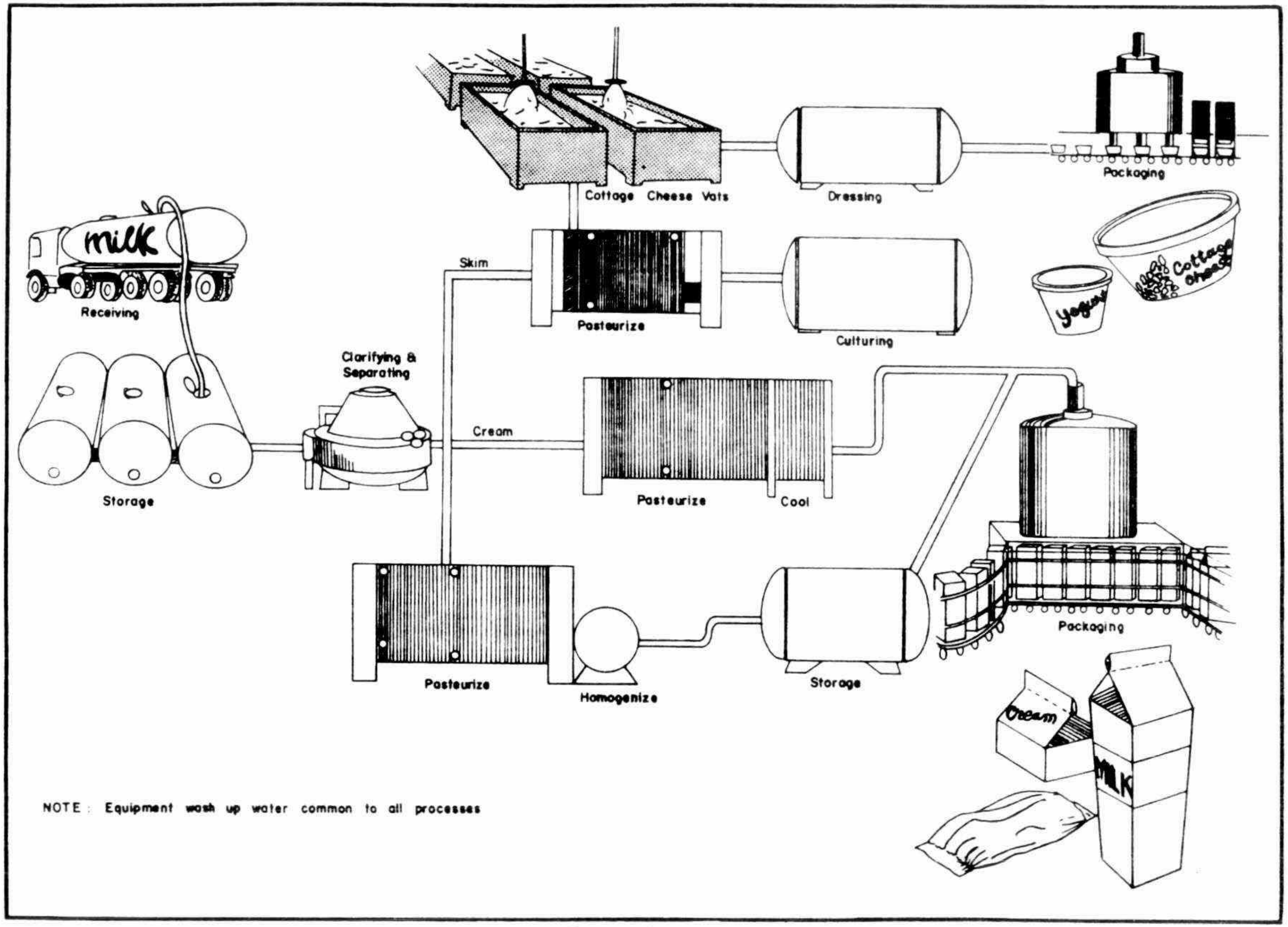
The sources of wastes are leaks, spillages and the wash waters used to clean equipment. These wastes require some form of treatment before they are discharged to a watercourse. Because these plants are usually located in urban municipalities, treatment generally takes place in a municipal sewage treatment plant. The cooling waters are normally uncontaminated and can be discharged to a storm sewer or directly to a watercourse.

(5) Fluid Milk

Fluid milk establishments produce milk and associated products such as skim milk, 2% milk, etc., and cottage cheese as a by-product. The fluid milk industry has expanded over the past years and this trend is expected to continue as population growth increases. With improved transportation, larger plants are being constructed in urban municipalities and distributing their products over wider areas.

Raw milk, normally received in tank trucks or in 10-gallon cans, is pumped to refrigerated storage tanks prior to use. It is clarified (strained) in centrifuge devices or, in smaller plants, by the use of small mechanical filters. The clarified milk is pasteurized in continuous flow or batch type pasteurization units. It is homogenized to break up the fat particles so that they remain in suspension. In some cases, it may be necessary to "deodorize" the milk to remove any off-odour or off-flavours. This is done by vacuum steam injection in bad cases or simply using a vacuum treatment in milder cases. After this treatment, the milk is cooled and sent to storage and packaging. Milk may be packaged in bottles, cardboard cartons, plastic containers, etc., after which it is sent to cold storage prior to distribution.

The fluid milk plants often produce cottage cheese as a by-product. The pasteurized milk is cooled to the desired "setting" temperature and pumped into cheese vats where it is innoculated with a bacterial culture. At the end of a controlled period of time, the curds are separated from the whey, cut into small pieces, and cooled. The whey is discarded as waste or sent on as a by-product for further processing. The cheese is dressed with cream, milk or fruits, and packaged ready for distribution. A flow sheet of the operations for a fluid milk plant is summarized in Figure 9-5.



NOTE: Equipment wash up water common to all processes

Figure 9-5
Flow Chart - Fluid Milk

Wastes arise from leaks, spills and from washing of equipment. These contaminated wastes must be treated, often in a municipal plant. There is also cooling water which is uncontaminated and which may be discharged to a storm sewer or watercourse.

Waste Handling and Disposal

(1) In-Plant Control

The first control procedure is good housekeeping, regardless of whether the wastes are treated privately or discharged to the municipal sanitary sewers. Spills, leakages, bottle breakages, etc., must be minimized in order to reduce product losses. Minor losses of milk can affect the quality of the final effluent. Cooling water from pasteurizers, compressors, and refrigeration units should be segregated and discharged to a storm sewer or watercourse to reduce the hydraulic loading on the treatment system. Cooling waters do not normally come in direct contact with the product. They are uncontaminated and acceptable for direct disposal to a watercourse.

Some recent developments in the industry have increased production and at the same time reduced waste flows. More milk is now received at the plants in tank trucks than in 10-gallon cans. This reduces spillage and the amount of water used in the cleaning operation. The change from batch operations to continuous flow operations has produced a more consistent quality of waste and reduced the frequency of washing down equipment. The packaging operations are more sophisticated and spillages have been reduced considerably. The packaging of milk in paper cartons has reduced the need for washing bottles returned to the dairy for re-use. Smaller operations have shut down and have been replaced by larger plants located in urban municipalities. More efficient larger plants can operate at a higher profit margin and can better afford to install wastewater control measures.

Dairy wastes are organic in nature, exerting a high BOD. The material causing the BOD is in a soluble form which cannot be removed by screening or settling in conventional equipment. Dairy wastes cannot normally be treated in the primary section of a treatment plant. Any batch discharge to the sanitary sewer will exert an immediate loading on the aeration section. To prevent extreme shock load effects, some form of control must be provided at the plant.

Equalization facilities are needed to mix the wastes and to allow a more uniform effluent discharge to the sanitary sewer. It is desirable to store wastes during the day for discharge to the sewer at night when the domestic waste flow is low. These are the two simplest control methods available.

(2) Pre-Treatment

Pre-treatment systems available to the dairy industry are similar to those for other organic wastes. However, dairy processing wastes can usually be discharged to a sanitary sewer for ultimate treatment at a sewage treatment plant.

Dairy processing wastes exert a direct and almost immediate load on the aeration section of the sewage treatment plant and it is imperative to determine the exact waste loading contributed by the industry. When all in-plant control measures have been implemented and good equalization of wastes is being effected, it must be determined if the sewage treatment plant has the necessary capacity to handle the industry's waste loading. If the capacity is insufficient, the industry will be required to provide pre-treatment to reduce this loading for satisfactory handling at the sewage treatment plant. The type of pre-treatment system and the amount of pre-treatment depend entirely on the type and capacity of the sewage treatment plant. The type of pre-treatment would be biological:

(a) Trickling Filters

Trickling filters can be used quite effectively to provide initial treatment of organic wastes and render the effluent acceptable for disposal to a sanitary sewer. Dairy processing wastes are readily biodegradable. In Ontario, trickling filters are not popular since the treatment efficiency is low in the winter months. With dairy wastes, these units could be quite small and installed under cover to eliminate problems associated with winter operations.

(b) Aerated Lagoons

Aerated lagoons can also be used to reduce the waste loading from the dairy industry to acceptable levels for discharge to a sanitary sewer. The designs of these systems may vary from a fully-mixed activated sludge to a facultative aerated lagoon, depending upon the degree of pre-treatment required.

(3) Complete Private Treatment

The industry may wish to install its own wastewater treatment system and discharge the wastes to a storm sewer or watercourse rather than to a sanitary sewer. Here the handling methods are more varied:

(a) Land Disposal

(i) Spray Irrigation

In this instance, wastes are collected, screened, and applied on land through a series of pipe lines and sprinklers. Dairy wastes are suitable for land disposal, but should not be allowed to overload the land. Dairy wastes in particular become septic quite easily and cause odour and nuisance problems. Sufficient land must be available to keep application rates as low as possible.

In winter, when it is impractical to spray the wastes, the company may be required to provide a storage lagoon to retain all wastes produced during winter operation. These wastes can then be sprayed on land, starting in early spring as weather permits. These lagoons can be a source of odour in spring when the ice cover breaks up, but this is normally a temporary condition and should not last for more than one week. Masking agents and nitrates may be used to overcome some of these odour problems.

(ii) Ridge and Furrow

Ridge and furrow can also be used as an effective means of land disposal if minor modifications are made to the system. The longer and shallower the furrows, the less time the wastes remain as puddles in the furrows. This should prevent septic conditions from developing. The furrows should be plowed more often since fats in the milk may seal the soil and prevent the wastes from leaching into the ground.

(iii) Haulage and Spreading on Land

In some very small operations, the wastes can simply be collected at the end of the day, hauled away, and spread on land. Cheese plants often spread whey on rural roads to cut down on dust problems. Proper application must be practiced to prevent ponding and odour problems.

(b) Biological Treatment

A number of biological systems available to the industry are capable of producing an effluent acceptable for discharge to a natural watercourse. These systems are complex, requiring a substantial expenditure, both for capital and operating costs. They are normally installed only by the larger industries.

(i) Aerated Lagoons

Aerated lagoons with sludge recycle have been extremely effective in treating dairy processing wastes in Ontario. The sludge is normally settled in clarifiers and returned to the aerated section. Various means have been used to introduce air into the wastes, although it appears that surface aerators are the most popular.

(ii) Oxidation Ditches

Oxidation ditches are also used to treat dairy processing wastes. Initially, problems were encountered with the bushings at the end of the rotors. These problems have been overcome and these systems are now very effective.

(iii) Activated Sludge

Conventional activated sludge plants have been constructed to treat dairy processing wastes. These systems are complex and expensive and are normally installed only by the largest industries.

CHAPTER X

MEAT PACKING AND RENDERING

Introduction

In the 17th and 18th centuries, meat was preserved by packing it in salt in wooden barrels (which is how the term "meat packing" originated). This term has continued to be used but does not completely describe today's multi-million dollar industry. Meat packing is Canada's largest food industry, ranking it third following the motor vehicle and pulp and paper industries.

Companies engaged in meat packing vary widely in economic scale, general type of operation and degree of government supervision. 80 percent of Canada's meat supply is processed in 300 federally inspected plants, while another 1,000 smaller plants operate under provincial or local inspection systems to produce the remaining 20 percent. A major meat plant will slaughter all species of meat animals and process the carcase into fresh meat, cured and smoked meats, cooked meats and sausage products, and canned meats.

Some of the major plants are engaged in processing edible and inedible by-products. This latter processing includes lard, leather, soap, and animal feed production. Many of the smaller plants carry out only slaughtering and processing of the carcase into meat quarters or finished meat cuts for individual and retail requirements.

Meat Packing

Processes, Sources and Characteristics of Wastewaters

In large modern slaughterhouses (abattoirs), killing and subsequent processing is a production line operation. Workers perform a specific operation at stations on the production line. Figure 10-1 and Figure 10-2 show the basic operations.

Killing is carried out in one of several ways, depending on the type of animal involved. Cattle are usually stunned

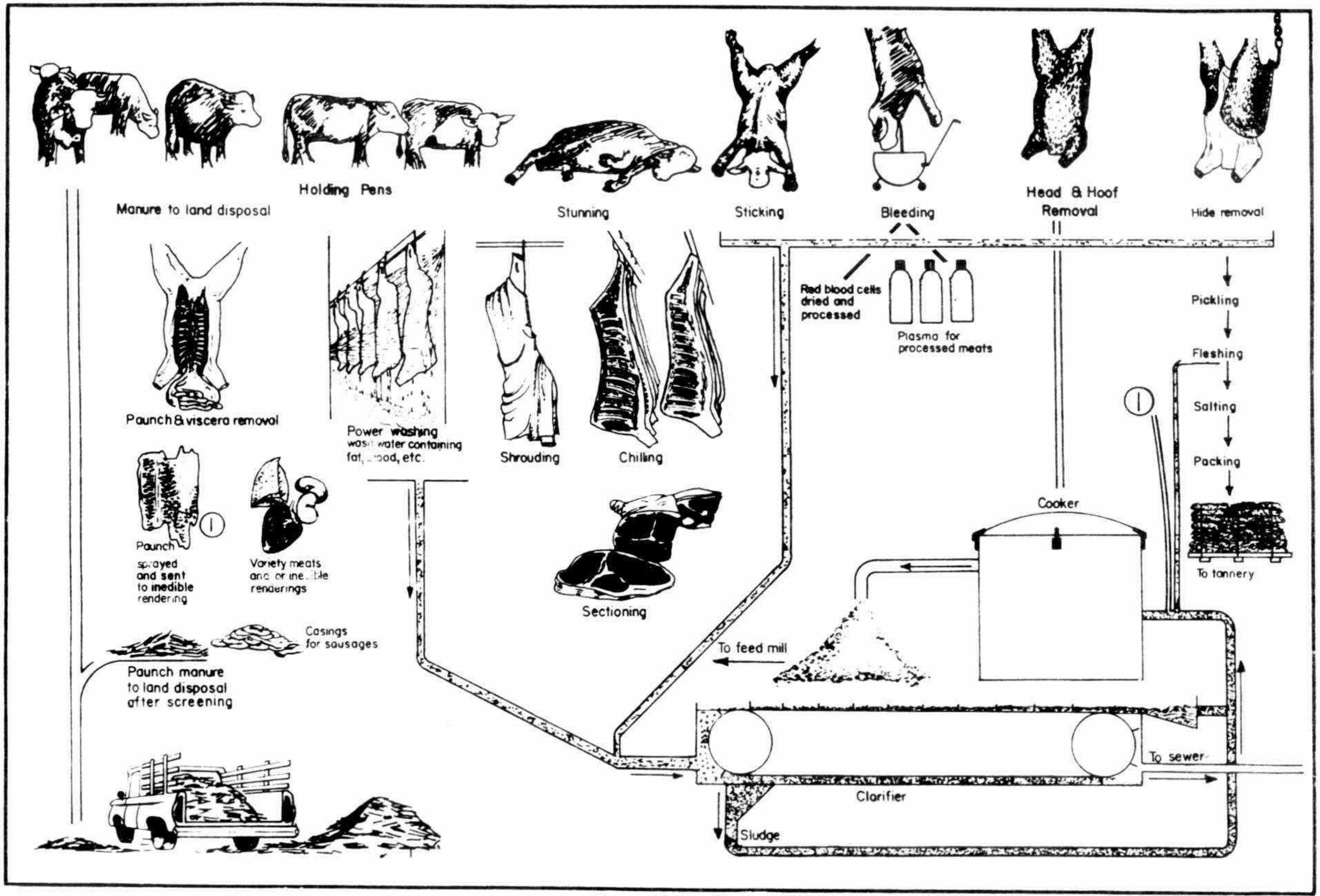


Figure 10-1
Flow Chart - Beef Packing

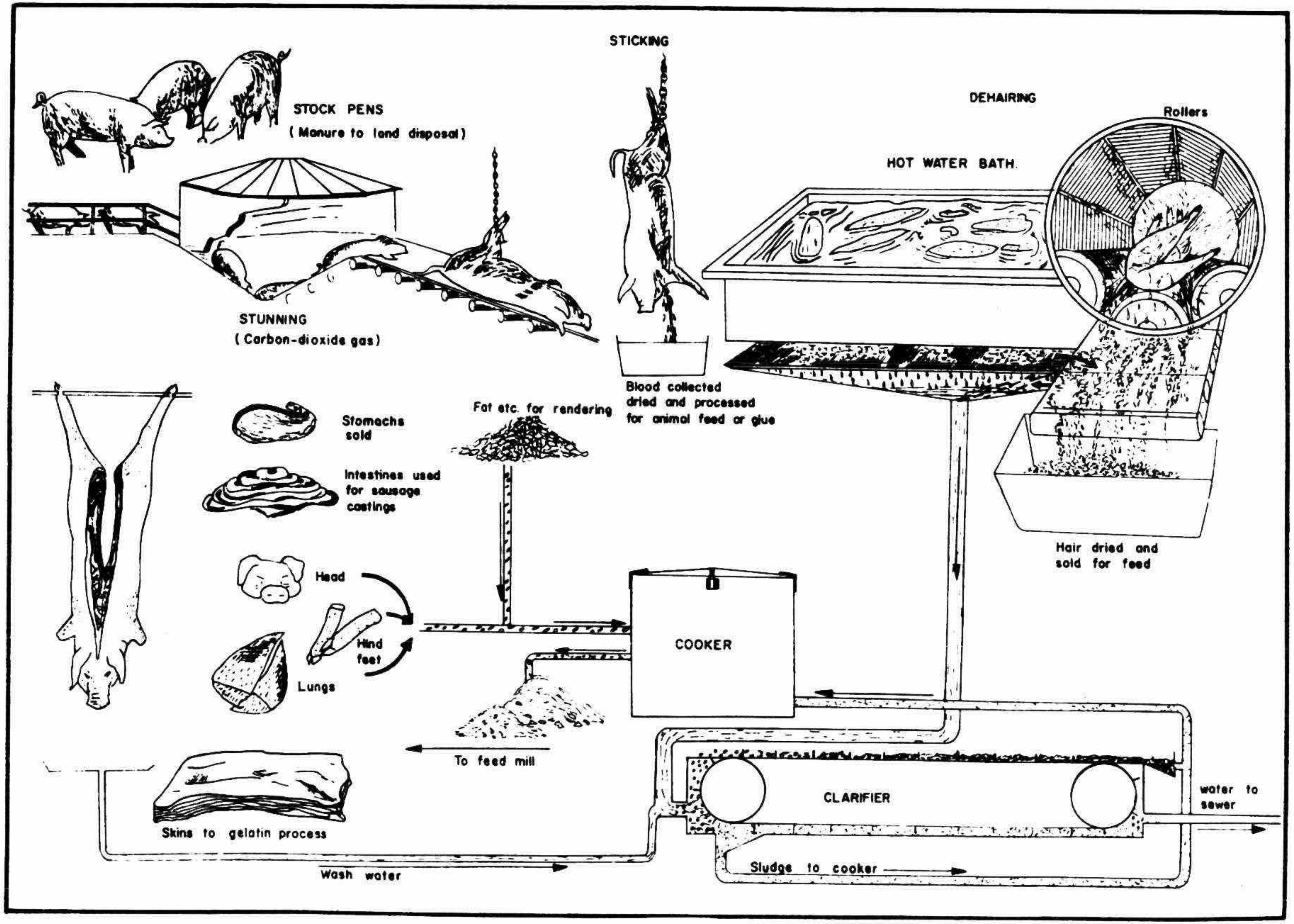


Figure 10-2
Flow Chart - Pork Packing

by a steel ball fired from a 2,000 psi air pressure device, or are shot directly with a small calibre cartridge. Hogs are inactivated in a carbon dioxide atmosphere or are shot with a cartridge. Following any of the above, the jugular vein of the animal is cut to permit rapid free bleeding. This blood is the highest potential source of wastewater pollution loadings and should be treated accordingly. Large slaughterhouses usually collect the blood for further processing into by-products or arrange for collection by contract renderers. Nearly all of an animal's blood can be drained when given sufficient time.

On a beef production line, the animals are hung on a conveyor by a hind leg. The head is removed first, together with the lower part of the legs. Next, the abdomen is opened and the whole contents removed. This removal includes stomach, heart, liver, kidneys and intestines; the combined weight of these organs is approximately 80-90 pounds. The edible organs (heart, liver, kidneys) are separated from the inedible organs (stomach and intestines) which are directed to disposal. As the carcase progresses along the production line, the hide is stripped, and fat and other minor solid parts are cut away. Hogs are dehaired by immersing the carcase in hot water and mechanically vibrating the skin. The small trimmings are usually collected for edible rendering. The carcase is then washed thoroughly in a closed power spray washer. If the carcase is destined for the retail meat trade, it is shrouded and cooled rapidly, ready for refrigerated transportation.

WASTE SOURCES

All of the above operations take place on the 'killing floor' and this area is usually segregated from other processes. The major waste loadings arise from the blood drained from the animals being washed at different stages. Large quantities of small solid meat and fat particles also find their way into the wastewater flows. This total flow should be pre-treated. Screening through rotating or vibrating screens can remove the majority of the solid particles.

In the packinghouse, further processing takes place, such as cooking, curing, smoking and pickling. Some of the operations carried out, in addition to those concerning the processing of meat cuts, are: the manufacture of sausage and canning of meat; cleaning of intestines for casings; separation of intestine fat for oleo preparation, etc. From all of these operations, soluble organic materials and small fat and meat particles are picked up by the wash water. The waste wash water should be screened to remove the maximum possible amount of solids. If tripe processing is carried out, the content of the animal's stomach (paunch manure) must be disposed of. This material is usually wet flushed away and screened. The screenings can be hauled away for land disposal. All other meat and fat screenings are collected and usually directed to rendering.

Treatment of Wastewaters

Given appropriate pre-treatment, the wastewaters from the slaughterhouse or packinghouse located in a municipality are acceptable for further treatment at the municipal sewage treatment plant. The waste loadings will vary with the size of the operation involved and the degree of pre-treatment given before discharge to the sanitary sewer. Some municipalities may charge the industry for waste treatment.

If the slaughterhouse or packing plant is not located with access to a sewage treatment plant, it must provide its own waste treatment. The large slaughterhouse and packing plants operating their own waste treatment facilities invariably choose biological treatment. The wastes are readily amenable to biological degradation. Many different types of systems are chosen, anaerobic and aerobic stabilization lagoons, facultative aerated lagoons or activated sludge (usually extended aeration modification).

Poultry

Poultry Processing

In recent years, through the use of mass production techniques, the poultry industry has grown rapidly into a high volume, low unit-cost operation. To lower production costs, operations are being continually enlarged and consolidated. In Ontario, most of the major poultry processors are now wholly owned subsidiaries of the large animal feed supply companies. The trend is to larger processing plants and some Ontario plants can process up to 60,000 chickens per day. In the bigger U.S. plants, up to 150,000 chickens per day are processed.

Poultry processing operations are similar to meat packing operations and the associated wastes are also similar. In a typical processing operation, the chickens are brought to the plant in cages on open trucks. The birds are manually removed from the cages and hung by their feet to a travelling conveyor. They are stunned by an electrically charged wire system. The successive operations are then: killing, bleeding, scalding, defeathering, picking, singeing, eviscerating, washing, chilling, weighing and packing. The operation is carried out in assembly line fashion, with each worker carrying out a specific job. Figure 10-3 is a process flow chart.

Most large poultry processing plants operate on the "flow away" system; the waste materials, feathers and solids are continuously removed from the originating area by steadily flowing water. The wastes produced may be divided into processing wastes and clean-up wastes. Processing is usually carried out over an 8 to 10-hour period followed by a clean-up period of several hours.

Sources and Characteristics of Wastes

(1) Killing and Bleeding

The jugular wein is cut to permit free bleeding. Each chicken contains approximately 1/6 of a pint of blood. BOD_5 of blood is 100,000 ppm and the maximum volume must be collected for efficient pollution control. Killing and bleeding should be carried out in a sloped tunnel and the blood collected in suitable containers. Rendering companies will take blood together with offal and feathers for conversion into inedible oils, fats and animal feed.

(2) Scalding

This is carried out to assist defeathering. The hot water continuously overflows and contains appreciable quantities of blood and feathers.

(3) Defeathering

Feathers are removed mechanically in counter-rotating steel drums with mounted rubber "fingers". The feathers are flushed away continuously and should be collected by

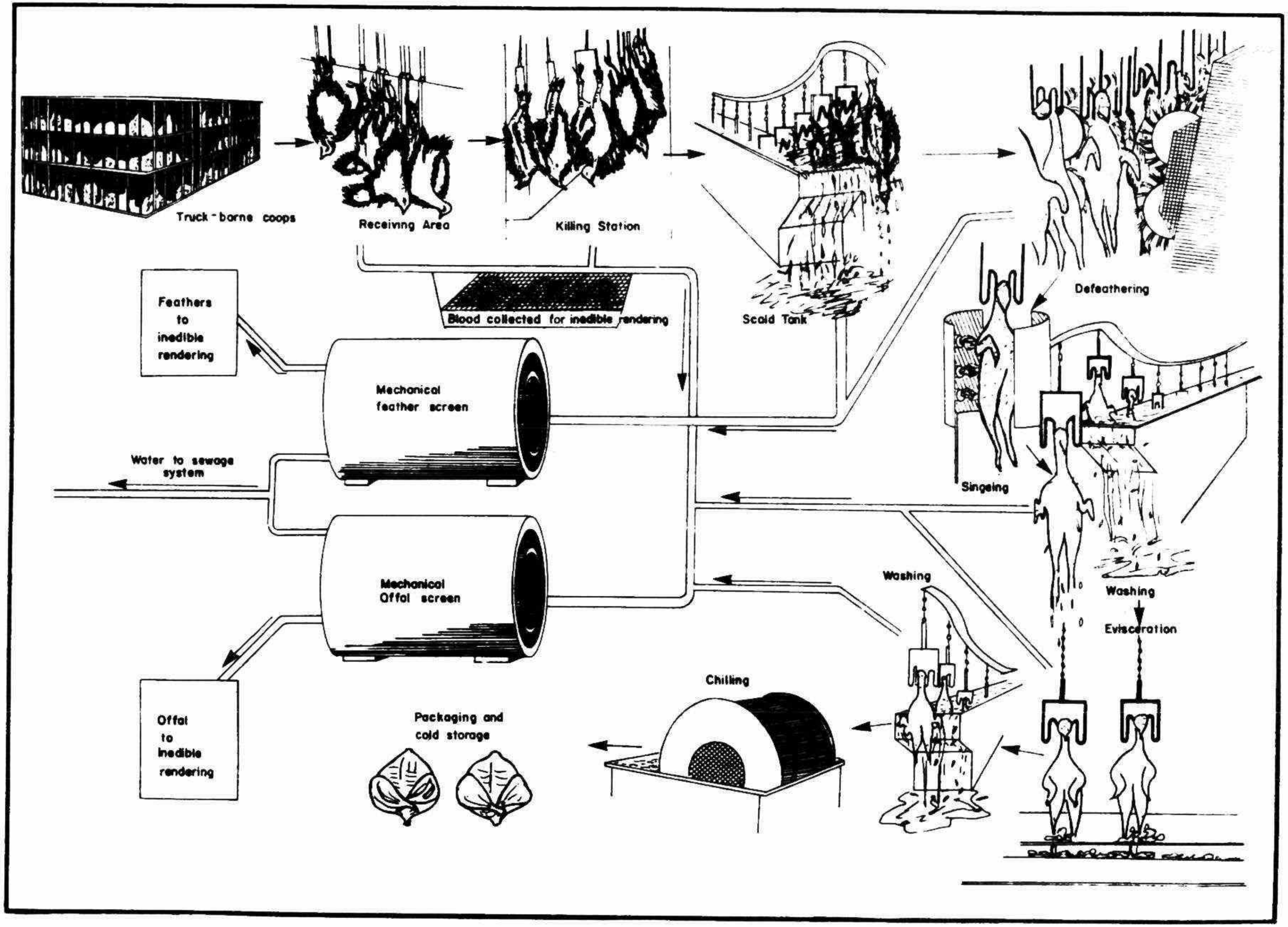


Figure 10-3
Flow Chart - Poultry

suitable screening. Water from this operation contains the small "pin" feathers passing the screens and high concentrations of organic pollutants.

(4) Cutting and Evisceration

This is carried out in an area strictly segregated from previous operations. At this point, the lower leg portion is removed, followed by removal of the viscera. Federal or Provincial inspection is carried out at this stage and diseased birds are rejected. Inedible viscera are continuously flushed away. The birds are thoroughly washed inside and out before leaving the area. Flow-away water contains a high concentration of large and small solids and soluble organic material.

Screening should be carried out on the flow-away water from the above operations to remove suspended solids. Many types of screen are in use for this purpose. Both the vibrating rotary type screen and the rotating drum screen are satisfactory for this wastewater stream.

(5) Chilling and Packing

The processed poultry now moves to the chilling stage where body heat is removed as quickly as possible to maintain flavour and storage life. Chilling is carried out by immersing the birds in successively colder water baths which overflow continuously. An efficient system will quick-chill eviscerated poultry to around 35°F in 25 to 30 minutes. The majority of the poultry is then packed in ice in insulated paper box containers and shipped in refrigerated trucks. If the poultry is to be frozen, it is wrapped and fast frozen. Before shipping, all poultry is weighed and graded.

The wastewater from these operations is usually of low BOD_5 concentration and contains only small quantities of suspended solids. It is not necessary to use the screens associated with evisceration for this wastewater.

Waste Treatment

A plant processing 20,000 chickens per day has a "population equivalent" of 5,000; the waste loadings from the plant equal the sewered wastes of a town of 5,000 population. An Ontario-wide survey indicated that the average waste loading from poultry processing plants is approximately 29 pounds BOD_5 per 1,000 birds processed. Water consumption varies between 5 and 10 gallons per bird.

The majority of poultry processing plants use flow-away wastewater systems. Plants located in a municipality with sewage treatment plant service carry out pre-treatment of the wastewaters and then discharge to the sanitary sewer. The municipality will often charge the company for this service, but this means of disposal is more economical than if the company treated its wastes completely in its own specially constructed facilities. The pre-treatment facilities should include blood collection, feather screening, offal and viscera screening and possibly grease separation. Blood collection is the most important aspect of pollution reduction. The overall waste loadings from a poultry processing plant can be reduced up to 40 percent by efficient collection.

If the plant is not located in a municipality serviced by a sewage treatment plant, independent treatment facilities are required. This means additional treatment beyond the in-plant pre-treatment. Efficient pre-treatment is equally important since any reduction in waste load reflects directly on final treatment capital and operating costs.

Final treatment for poultry plant wastewaters is usually biological. The wastes involved are readily biodegradable and biological treatment is more economical than other alternatives. Most plants in Ontario use extended aeration, a modification of the activated sludge process, because:

(1) shock loadings do not affect the process as seriously as the conventional activated sludge plant;

(2) operational flexibility is better;

(3) very little excess activated sludge is produced, so sludge disposal is minimized; and

(4) operator attendance is reduced and process

operation is simplified.

Air is usually supplied to the biological treatment unit by mechanical surface aerators. After the effluent is clarified, it must be chlorinated before it is discharged to a receiving watercourse.

Rendering

Rendering provides a valuable contribution to overall waste control by converting waste materials from the meat packing and poultry processing industries into useful by-products. (The material produced is high in protein.) The utilization and recycling of waste materials is essential in future pollution control.

Large meat packing plants may have an integral rendering operation to handle their own waste materials. Small plants usually have contracts with plants who specialize only in process rendering.

There are two types of rendering: edible and inedible, but these refer only to human consumption. For edible rendering, the processing is carried out under stringent hygenic conditions. Inedible rendering includes those wastes classified as unsuitable for human consumption, such as animal and poultry viscera, blood, bones, feathers, skin and fat.

Wet rendering involves cooking the waste in hot water tanks and skimming off the liberated fat and grease. The method is not widely used now and may be confined to some hog renderings for the production of lard. The residue from any wet rendering, plus all the other waste materials, is normally dry rendered. This rendering is carried out by heating the materials to remove moisture and grinding the resultant material to produce a granular meal. The product meal can also be further dried or squeezed for fat removal.

FIGURE 10-4

FLOW DIAGRAM

Raw Material → Crushing → Cooking → Fat Removal → Grinding → Storage → Shipping

There are two rendering systems: one uses batch cookers, the other uses continuous cookers. In both types of cooker, the material is heated to 250°-260°F by indirect steam. At these temperatures, the moisture in the material, normally 50-70 percent, is driven off and the complex preteins are broken down. Fat is released and separates out as "tallow". The tallow is drained off and the cooked material fed into a filter for additional fat removal. Both fat and meal are subjected to further processes before storing for eventual sale.

Wastewater Sources

The major source of wastewater is the water contained in the raw material. Since this may constitute as much as 50-60 percent of the raw material, the volume is considerable. A large rendering plant may process up to 2,000 tons of waste per week. This would result in approximately 240,000 gallons/week of water expelled from the raw material. The water is driven off as steam during cooking and contains steam-distilled organic compounds including amines, aldehydes, mercaptans, fatty acids and sulphides. These gases and vapours must be condensed, usually by either surface condensors or barometric condensors. The surface condensors are often cooled by water from a closed circuit cooling system. In barometric condensors, the cooling and condensing is achieved with direct contact of water. Thus, the volume of condensate from the raw material is mixed with the barometric cooling water. Waste strength of these condensates can range up to 10,000 parts per million BOD_5.

Another major source of wastewater arises from floor, equipment and truck washings, spills, and other minor processes where water is used. This wastewater usually contains high concentrations of suspended solids, emulsified fats and soluble organics. The volume will be dependent upon the size of the rendering plant. The BOD_5

ranges from 1,000 to 2,000 ppm.

If the rendering plant or operation is located in a municipality with a sewage treatment plant, the wastewaters, following pre-treatment, would normally be discharged to the sanitary sewer. The minimum pre-treatment is screening and the maximum, screening and grease separation. Grease separation is usually accomplished by a conventional grease separator or, less frequently, in a dissolved air flotation unit. Good housekeeping practices during rendering operations should ensure the minimum quantity of solids and grease in the final wastewater discharge. Dissolved solids, emulsified fats and soluble organic material in the wastewaters are a "product loss". They are also the pollutant materials that exert a high oxygen demand.

When a rendering plant is not serviced by a municipality, waste treatment beyond the in-plant pre-treatment is required. One large Ontario rendering company has successfully established an almost total recycle operation where the wastewaters are stabilized in large ponds and eventually recycled as barometric condensor water. Another large company successfully spray irrigates all its wastewaters onto suitable adjacent land.

CHAPTER XI

TANNERIES

Tanning is the process by which a skin is brought to a stable condition and will not putresce. In addition, tanning improves certain properties of the material, such as resistance to abrasion and heat, flexibility and resistance to damage from cycles of wetting and drying.

The skin as removed from the animal consists of three layers: the epidermis, the corium and the flesh. The epidermis and flesh are not suitable for leather making and are removed. The corium consists mainly of a protein, collagen. The reaction of this protein with tannin or chromium results in the formation of leather.

When the skin is removed from the animal, it must be cured as soon as possible to prevent bacterial attack. Normally, this is done by covering the hide with salt. The salt removes water from the hide; this dehydration is responsible for preserving the skin.

The tannery consists of four main processing areas:

1. the hidehouse;
2. the beamhouse;
3. the tanyard;
4. the finishing department.

1. The Hidehouse

Cured hides are received and are stored until required. Hides from large animals are usually cut into two or more sections for ease of handling. The common practice is to split them lengthwise into sides, at the same time trimming off the unwanted parts. The sides are then made up into "packs" weighing approximately 5,000 lbs. Each pack is processed through the tannery as a unit.

2. The Beamhouse

Three main operations are carried out in the beamhouse:

(a) Soaking

Soaking restores natural moisture removed by the salt in the curing process. It is carried out in vats equipped with rotating paddles which move the hides around in the soak water. Dirt, manure, blood, salt, fat, etc., are removed during the soaking process.

(b) Unhairing

Unhairing removes hair, epidermis and certain unwanted proteins. A solution of lime and sodium sulphide removes or dissolves the hair according to the strength of the solution, the temperature and the amount of agitation.

(c) Fleshing

Fleshing removes flesh and fat which may be present using a machine with rotating blades which scrapes off the unwanted material.

Note: Fleshing may be carried out before unhairing or may be carried out at the slaughterhouse.

3. The Tanyard

After the beamhouse operations, the hides are free of hair, clean and somewhat swollen by the alkali used in unhairing. Tanyard operations include the following steps:

(a) bating
(b) pickling
(c) tanning
(d) wringing
(e) splitting and shaving
(f) retanning
(g) colouring
(h) stuffing and fatliquoring.

(a) Bating

The alkaline unhairing chemicals which are still present in the hide must be removed. This is known as deliming and the process is assisted by the addition of certain chemicals. When deliming is complete, the bate is added and is allowed several hours to work, after which the hides are washed with water.

Bating removes the skin substances which do not form leather by the use of enzymes (bates) similar to those found in the digestive system of animals.

Note: Some modern bates are mixtures of deliming chemicals and enzymes to carry out the bating process in a single step.

(b) Pickling

Pickling places the hides in an acid condition ready to receive the tanning material. Any of a number of acids may be used but before the acid is added, salt must be introduced to prevent a condition known as "acid swelling". An acid pH (less than 7) is required since the chrome tanning chemical is not soluble in alkaline conditions.

(c) Tanning

Tanning converts the hides into a stable non-putrescible material. Certain chromium salts are most commonly used, although many materials will combine with skin protein to form leather. Vegetable tanning and synthetic tanning agents such as phenolsulphonic acid-formaldehyde complexes are also used. The solution of tanning material is added to the hides in a drum which is rotated during the tanning process.

(d) Wringing

Wringing removes excess water from the leather. This is done using a machine with two wringer rolls through which the leather is fed.

(e) Splitting and Shaving

Splitting and shaving adjusts the thickness of the leather as required to achieve uniform thickness. The splitting *machine consists of a horizontally moving blade which slices the piece of leather. The thickness of the grain (outer) side of the leather is uniform while that of the flesh side (called a "split") may vary. Although the split has no grain, it may be used to produce sueded leathers. Shaving is done on a machine similar to a fleshing machine and is used to adjust overall thickness to exact specifications.*

(f) Retanning

Retanning imparts the desirable properties of the retanning agent to the leather. The tanning process is similar to the original tan.

(g) Colouring

Colouring imparts colour to the leather.

(h) Stuffing and Fatliquoring

Stuffing and fatliquoring lubricates the fibres for flexibility and softness. The leather is rotated in a drum either with liquid oils or with an emulsion of oils in water. The former is known as stuffing and the latter as fatliquoring. The softness of the leather, its flexibility, and its water repellence can be controlled by selection of an appropriate type and quantity of oil or fat.

The wet processing of the leather has now been completed and the remaining steps involve the use of little or no water.

4. Finishing

Finishing of the leather includes many processes designed to enhance the qualities of the leather.

The steps in leathermaking shown in Table A are as normally followed in a cattleskin tannery.

TABLE A

PROCESS FLOW

Wet Operations

1.	*Trimming and Sorting*	*Hidehouse*
2.	*Soaking*	*Beamhouse*
3.	*Unhairing*	
4.	*Fleshing*	
5.	*Bating*	*Tanyard*
6.	*Pickling*	
7.	*Tanning*	
8.	*Wringing*	
9.	*Splitting and Shaving*	
10.	*Retaining*	
11.	*Colouring*	
12.	*Stuffing or Fatliquoring*	
13.	*Setting Out*	

Dry Operations

14.	*Drying*	*Finishing*
15.	*Conditioning*	
16.	*Staking*	
17.	*Buffing*	
18.	*Finishing*	
19.	*Plating*	
20.	*Measuring*	
21.	*Grading*	

WASTEWATER CHARACTERISTICS AND WASTEWATER TREATMENT

A great amount of water is used to which is added a number of materials. All these materials appear in the wastewater in varying concentrations, depending on the purpose of the material and the conditions under which it is used. In addition, contaminants originating in the hides themselves are added to the waste stream. These contaminants include dirt, manure, urine, blood, lymph, fat and flesh, hair and protein. There is also the salt used in curing the hides. The wastewater from a tannery imposes such a large loading upon a municipal sewage treatment plant that pretreatment at the tannery is required in order to ensure compliance with by-law limits. Some of the characteristics of a typical tannery wastewater are compared with a typical by-law in Table B.

The tannery wastewater characteristics shown in Table B refer to the combined and equalized flow from all wet processes. Tanning is essentially a batch process so there may be a wide variation in sewage volume during the processing day. The origin of the main contaminants must be recorded. Figure 11-1 is a schematic flow chart showing the materials likely to be found in the wastewater produced at each wet processing stage. A number of different chemicals are used in the process and appear in the effluent; fortunately, only a few are of concern. For simplicity, consider only BOD, solids, chromium, sulphide, ether soluble material and pH. Table C shows the relative contribution of each of the processing steps to the total waste loading in terms of these components. The figures given are only estimates, since there is a wide variation in the method of sampling and analysis. The figures, however, do indicate the areas where the largest contribution of each contaminant occurs.

Since tanning is largely a batch process, the wastewater dumped in the sewer will have characteristics differing throughout the processing day. For example, the hairburn solution may have a BOD of 10,000 - 15,000 ppm and a pH of 12, whereas the spent chrome tan liquor may have a BOD of only 2,000 ppm, but a chromium content of 1,000 ppm and a pH of 3 or less. If each type of wastewater is discharged into the sewer as it is generated in the tannery, severe problems will occur in the sewers and in the treatment plant. Furthermore, the tannery effluent will not comply with the sewer-use by-law.

Tannery wastewater cannot be discharged into a sanitary sewer system unless some form of pretreatment is instituted to reduce BOD and solids content, remove sulphide and chromium, regulate pH, reduce ether soluble concentration and equalize flow. The flow should be regulated at a constant rate over 24 hours, no matter what the actual schedule of operations is within the tannery itself.

Certain portions of the wastewater may be used for mutual treatment, as in the case of hairburn and tanning solutions. The hairburn dump with its high pH and excess lime will treat, and be treated by, the pickling/tanning dump with its low pH and excess chromium. Some of the lime will be used up in precipitating the chromium and the pH will be brought within the by-law limits. Therefore, these

TABLE B

COMPARISON OF TANNERY WASTEWATER WITH A TYPICAL BY-LAW

	BOD	SOLIDS			Chromium	Sulphide	Ether Solubles	pH
		Tot.	Susp.	Diss.				
Tannery	2600	10530	2320	8210	75	50	0	8.4
Tannery	1500	5150	1570	3580	52	75	152	5.9
Tannery	1700	4830	1300	3530	8	25	82	6.6
By-law	300	-	350	-	3	2	150	5.5 -9.5

All above are in parts per million except pH

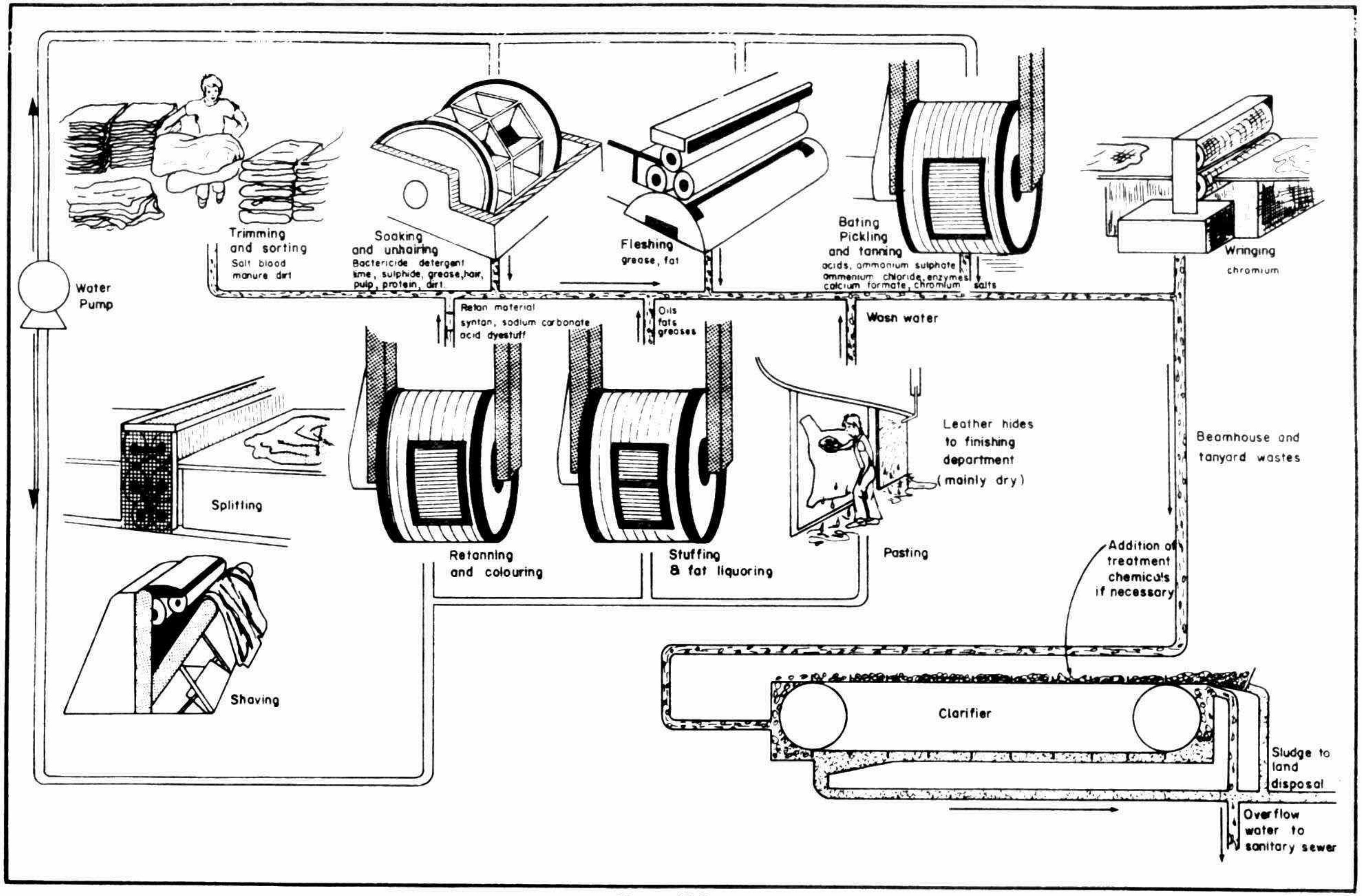

Trimming and sorting
Salt blood manure dirt
Soaking and unhairing
Bactericide detergent lime, sulphide, grease, hair, pulp, protein, dirt.
Fleshing
grease, fat
Bating Pickling and tanning
acids, ammonium sulphate ammenium chloride, enzymes calcium formate, chromium salts
Wringing
chromium
Water Pump
Retan material syntan, sodium carbonate acid dyestuff
Oils fats greases
Wash water
Splitting
Retanning and colouring
Stuffing & fat liquoring
Leather hides to finishing department (mainly dry)
Pasting
Beamhouse and tanyard wastes
Shaving
Addition of treatment chemicals if necessary
Clarifier
Sludge to land disposal
Overflow water to sanitary sewer

Figure 11-1
Flow Chart - Tannery

TABLE C

RELATIVE CONTRIBUTIONS TO WASTE LOADING

Process	% of water use	% of BOD	% of Solids	% of Chromium	% of Sulhpide	% of Ether Solubles
Soaking	18	18	30	-	-	25
Unhairing	24	45	40	-	99	50
Fleshing	2	5	10	-	trace	20
Bating	20	15	10	-	trace	trace
Pickling	5	4	1	-	trace	trace
Tanning		4	1	95	trace	trace
Wringing	1	trace	trace	5	trace	trace
Retanning	20	7*	6	-*	-	5
Colouring						
Fatliquoring						
Finishing and Miscellaneous	10	2	2	-	-	trace

* Depends on the type of retan

different types of wastes must be brought together. This may be a problem, since the operating schedule of the tannery may demand that both types be dumped at different times. The simplest solution is to collect an entire day's production of wastewater in a lagoon, mix it up and adjust conditions as necessary. This is impractical in most cases, due to a lack of space for large treatment facilities. Therefore, the strong solutions of opposite types must be segregated, collected and held until it is practicable to treat them. Since the pickle/tan spent liquor is of relatively small volume, it may be held in a storage tank and discharged into the waste treatment plant at the same time as the hairburn dump. If, however, it is necessary (as it almost always is) to remove sulphide from the waste stream, the hairburn dump should be treated, perhaps by catalysed oxidation of the sulphide, before it is mixed with the remainder of the wastewater.

The mixed wastewater must be treated to remove BOD, solids, chromium and grease. Clarification is the first step to remove most of the solids, most of the chromium, some of the ether soluble material and some of the BOD. Since combining the acid and alkaline wastewaters at most tanneries will result in a pH between 8 and 9, mixing the wastewater before clarification will normally ensure that the pH is in the correct range. If not, the pH must be adjusted by adding an appropriate chemical.

In some cases, clarification may be enough to meet the by-law limits. Usually, some further removal of BOD is required. Where space is limited, the activated sludge system may be preferred, although a trickling filter might also be used. Where space permits, lagoons or oxidation ditches can be considered.

Figure 11-2 is a flow chart showing typical steps required in minimum treatment of tannery wastewater. The chrome tan liquor is kept separate from the rest of the process wastes to allow its discharge into the wet well at the same time as the hairburn wastes.

The steps outlined in Figure 11-2 are the minimum required. In many cases, more sophisticated treatment will be required to ensure compliance with by-law limits. Figures 11-3 and 11-4 show more advanced systems.

The treatment steps outlined in Figure 11-4 should produce an effluent which will meet the terms of the most restrictive

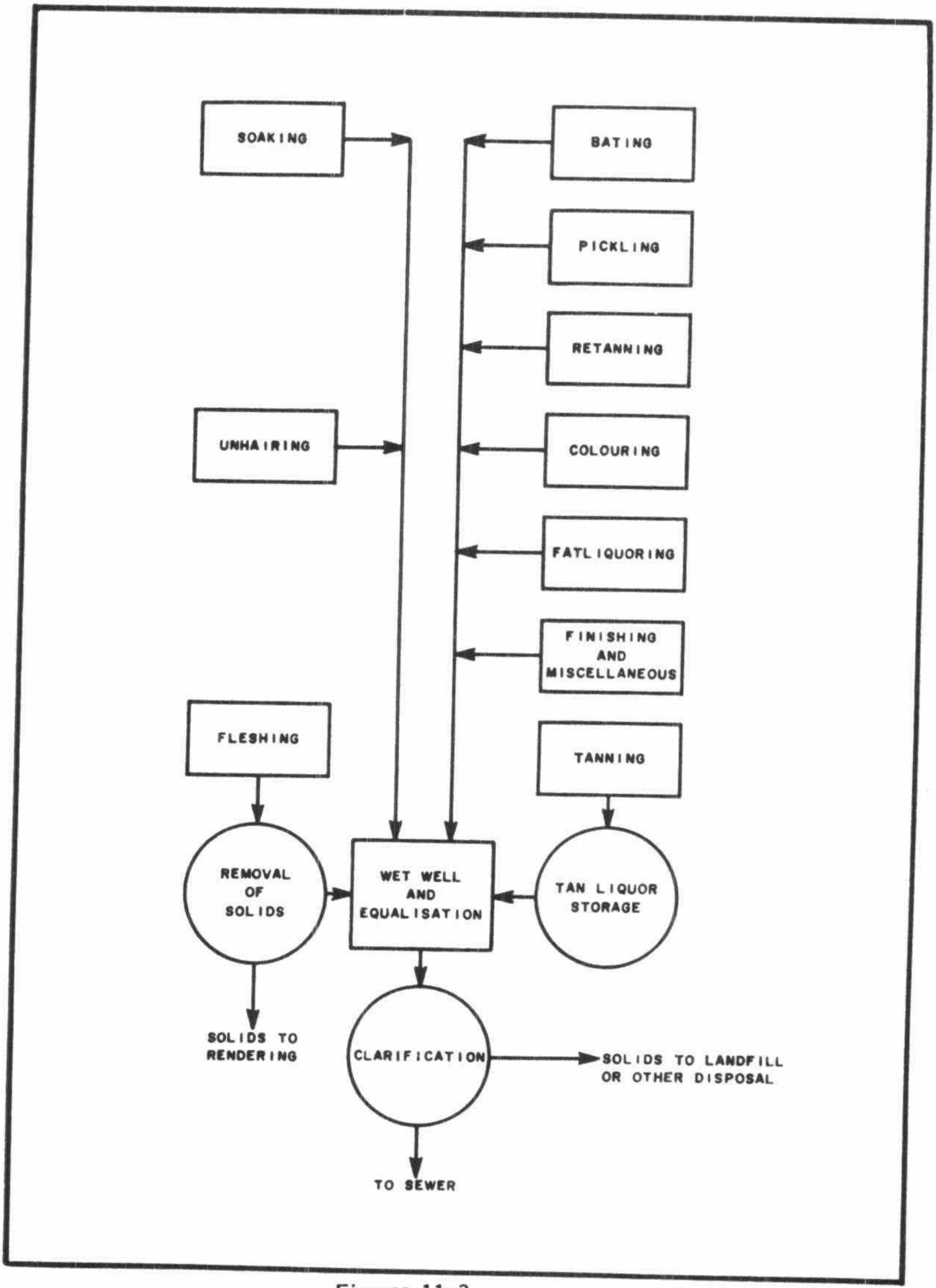


Figure 11-2
Wastewater Treatment - Minimum

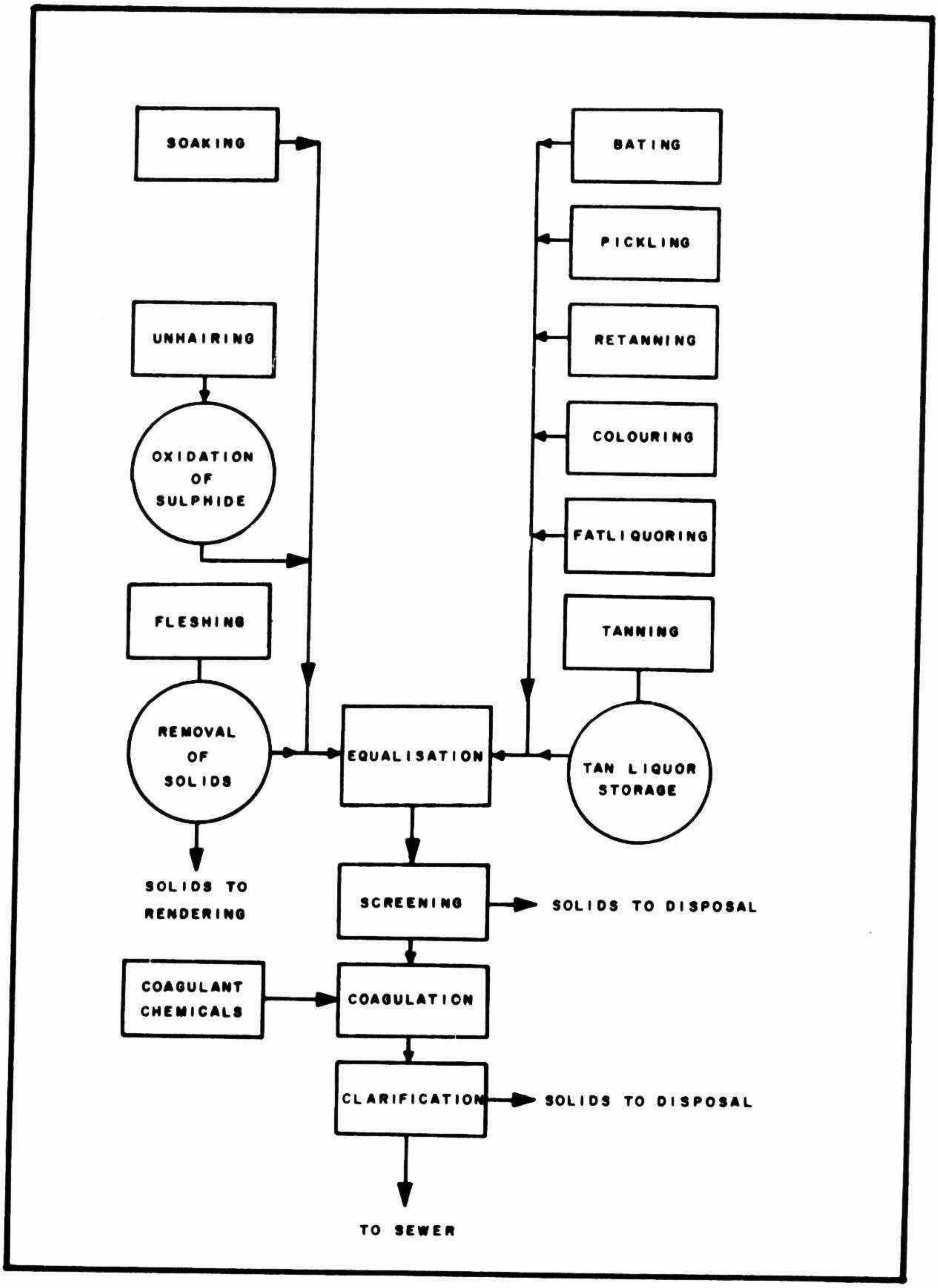


Figure 11-3
Wastewater Treatment - Average

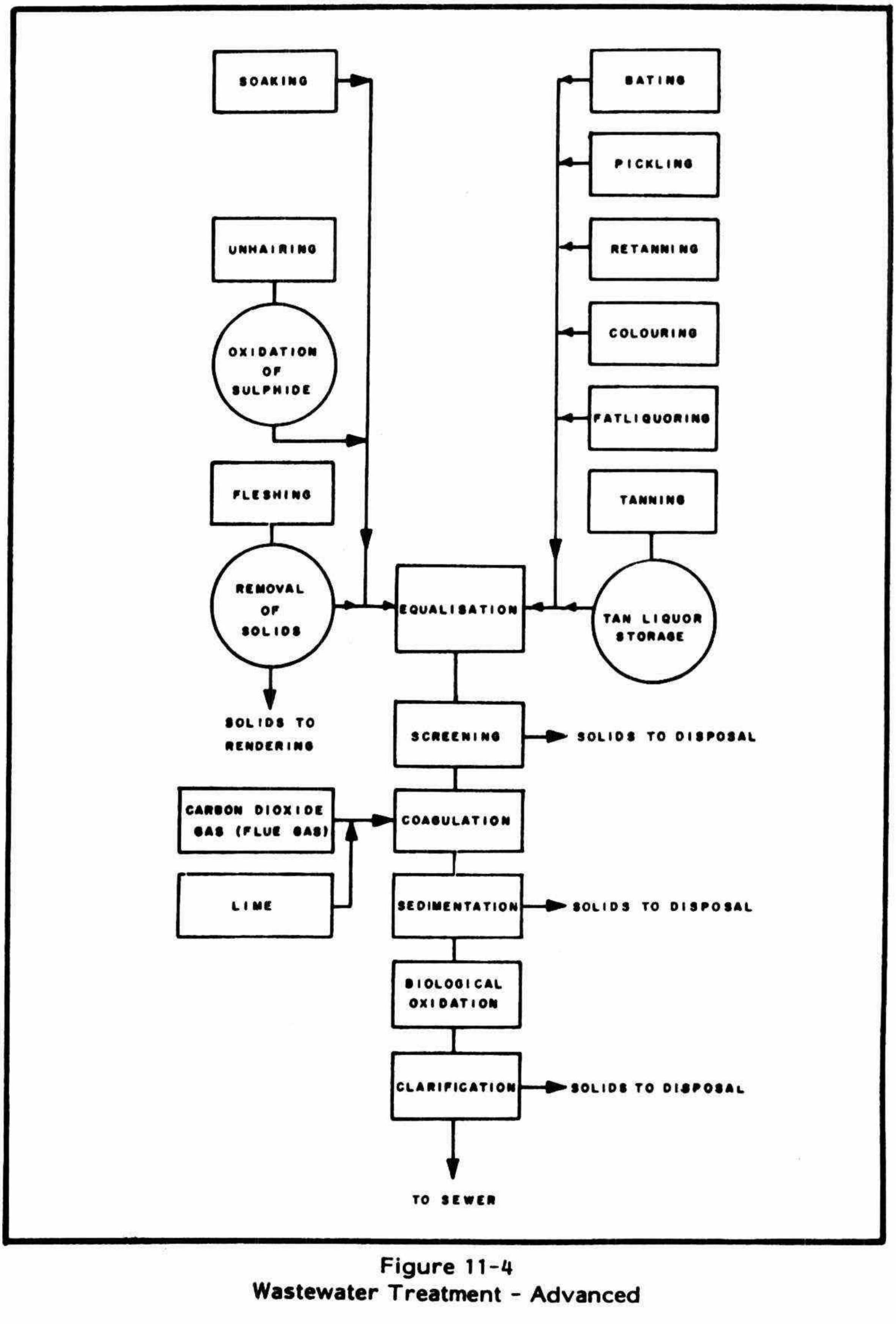


Figure 11-4
Wastewater Treatment - Advanced

by-law. Table D shows the efficiency which can be expected of various treatment steps in removing contaminants from the waste flows.

The correct combination of treatment steps allows any tannery to produce a wastewater which complies with the sewer-use by-law. However, while the general treatment principles outlined can be applied to all tanneries, the exact system employed in any case will depend on the circumstances.

Much of the waste produced at a tannery is unnecessary. Recycling and recovery of both water and processing chemicals is possible. Unhairing solution, tanning solution (and perhaps the bate) may be held for re-use, the correct reagent concentrations being maintained by suitable additions. The only requirement to effect such re-use would be holding tanks for the solutions and associated piping and pumping equipment. In the case of the unhairing solution, however, screening and sedimentation might be required.

If re-use is simple and acceptable from a quality control viewpoint, why has it not found favour with the tanning industry in general? The answer lies partly in costs, but more in the unsatisfactory wastewater handling techniques employed at most tanneries. Many plants are old. To rearrange the processing and drainage technology would be a major undertaking. Also, the tradition in tanneries resists and retards change. However, rather than introduce a mass of details on what can be done to reduce the quantity and upgrade the quality of tannery wastewater, consult the literature available for further information.

To summarize, tannery wastewater will normally require treatment before discharge into a sanitary sewer system. Acceptable treatment is relatively simple and need not be excessively costly, especially if re-use of solutions is practiced. The major treatment steps which may be required include screening, sedimentation, coagulation, equalisation, pH control, clarification, biochemical oxidation of organic material and oxidation of sulphide.

TABLE D

TREATMENT EFFICIENCIES

Treatment Step	Percentage Reduction of Contaminant				
	BOD	Suspended Solids	Chromium	Sulphide	Colour
Screening	5	5-10	0	0	0
Sedimentation	25-60	70-95	5-30	5-20	5-10
Coagulation	40-70	70-97	50-90	15-50	6-90
Activated Sludge	85-95	80-95	50-75	75-100	75
Sulphide Oxidation	5-10	0	0	75-99	0

CHAPTER XII

METAL INDUSTRIES: MANUFACTURING, WORKING, FINISHING

INTRODUCTION

The purpose:

(1) to review the industrial operations and the waste control and pollution prevention methods used in the metal manufacturing, working, and finishing industry.

(2) emphasize those portions of the industry that cause liquid waste effluents.

The metal industries will be discussed by:

(1) describing the industrial operations involved in metal manufacturing, working and finishing.

(2) identifying the various waste effluents with their sources within the plant.

(3) describing some of the pretreatment and treatment procedures which can be applied to these wastes before they are discharged to a municipal sanitary sewer or to a storm sewer or watercourse.

PLANT PROCESSES AND OPERATION

The metal industry is extremely varied. It ranges: (a) from aluminum anodizing to zinc plating, (b) from one-man shops to plants employing over 5,000 people, (c) from the production of the basic metal to the assembly of the final product.

METAL MANUFACTURING

(a) Steel

Steel making is a complex process. Products include steel strip, steel plate, steel rods and other shapes. Figure 12-1 illustrates the steps in its manufacture.

(b) Foundry Operations

Iron castings or other metals are produced by remelting the metal and pouring it into molds. In the case of iron castings, "pig iron", the product of the blast furnace, and scrap iron are charged into a furnace known as a "cupola". The cupola is charged with alternate layers of coke, metal, and limestone (as the fluxing agent). The molten iron falls through the coke bed and is withdrawn as required. At the end of the charge, the slag, made up of the limestone and collected impurities, is removed and water-quenched. The molten metal is poured into heat resistant sand molds and allowed to solidify. After a casting has solidified and cooled, it is shaken from the mold. Binding material such as linseed oil, wheat flour or resins, sometimes phenolic in nature, are used to provide strength to the sand cores. The sand used in making the molds is partially reclaimed for re-use; any "burnt" sand is discarded.

METAL WORKING

Metal working operations, performed on steel, copper, aluminum or some other metal, are extremely varied and include rolling, descaling, machining, stamping and annealing.

(a) Hot Rolling

The usual first step in metal working is termed "rolling", where the raw material - iron, steel or other metal - is rolled into sheets, pipes, rods, wire or coil as required.

In hot rolling, the metal ingot or slab is heated to make it much more malleable and ductile before it is rolled into the desired shape. The heat treatment applied forms

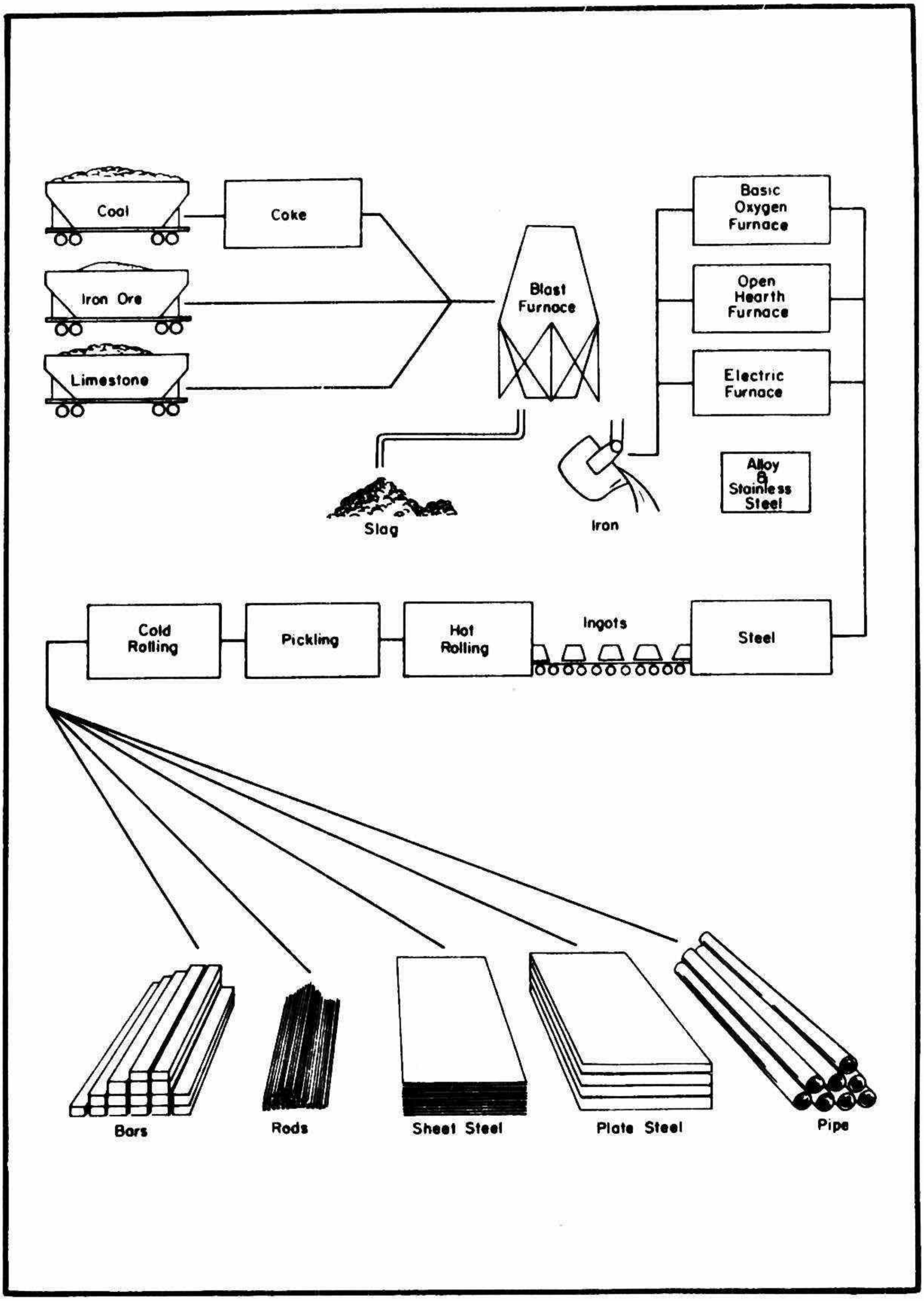


Figure 12-1
Steel Manufacture

a scale on the surface of the metal which must be removed before further processing.

(b) Descaling

Initially, the scale formed in hot rolling is removed by high pressure water sprays. This is followed by chemical or mechanical descaling. Chemical descaling is more effective and produces a cleaner product than mechanical methods. Dry mechanical methods such as sand blasting are preferred from a pollution control point of view and can be used depending upon the quality specifications of the product.

Chemical descaling of the basic steel (and other metals) utilizes either sulphuric or hydrochloric acid in a process known as "pickling".

(c) Pickling

Pickling can be either a batch or a continuous operation, depending on the semifinished form of the metal. In the simplest batch method, pickling consists of immersing bundles of scale or rust-encrusted steel in a vat of sulphuric or hydrochloric acid long enough to remove the scale while keeping direct acid attack on the steel to a minimum. A continuous decrease in acid strength with a resulting increase in pickling time is characteristic of the operation. This can be controlled temporarily by periodically adding fresh acid until ferrous sulphate starts to precipitate; then the batch must be dumped. This method of pickling permits very efficient use of the acid, but the length of time involved (30 to 50 minutes) is undesirable. A modification to the process uses several vats in series. The work is dipped in baths of decreasing acid strength followed by one or two water rinse baths. This provides efficient acid attack on the scale by contacting the heaviest scale with the strongest acid and a clean-up dip in a weaker solution.

Continuous pickling is possible only in the case of strip or sheet steel where the end of the first strip can be welded to the beginning of the next strip to form a continuous belt. The steel passes through several vats, arranged countercurrently as above. Continuous picklers operate rapidly with the total immersion time of the steel ranging from 30 seconds to a few minutes. This short reaction time is possible only at the expense of increased acid consumption. Solutions from batch picklers can often be discharged at a free acid strength of 1 to 2%, while the liquor from a continuous machine will seldom contain less than 5-7% free acid.

(d) Cold Rolling

After pickling, the material is cold rolled to further reduce the steel strip and remove surface blemishes. Heat generated during cold rolling is dissipated by flood lubrication using oil-water emulsions. After cold rolling, the steel may be given a temporary protective coating of grease if it is not immediately sent for further processing.

(e) Machining

Those operations which could be grouped under the general heading of Machining include grinding, drilling, boring, polishing, and cutting to give the metal its final shape. The raw material can be steel, iron, zinc, aluminum or other metals.

In those operations, a fluid is required at the tool-to-metal surface to provide lubrication, to remove the machined particles (the metal cuttings and filings), and to provide cooling. Straight "cutting" oil may be used, but where high cooling capacity is required, water is used. To provide lubrication and also to prevent corrosion of the metal part, a soluble oil is added to the water to form an oil-water emulsion.

METAL FINISHING

The metal surface must be finished by combinations of various operations depending on the desired properties of the final product. Included in these operations are vapour degreasing, alkaline detergent cleaning, annealing, a second pickling or sand-blasting treatment, buffing, galvanizing, electroplating, anodizing, chromating, phosphating, painting, and when necessary on rejects or reclaim work, paint stripping, and metallic coating stripping.

(a) Mechanical Surface Preparation

Mechanical Surface Preparation includes polishing and buffing, abrasive blasting and mass finishing. Polishing and buffing are essentially dry operations. Abrasive sand blasting is either dry or wet. In wet blasting, the abrasive is suspended in water which is then forced by compressed air to nozzles manipulated to remove surface metal contaminants. The slurry is constantly recirculated. Abrasive blasting is used for:

(1) removal of mold sand from castings, removal of scale, rust, paint and carbon deposits;

(2) roughening of surfaces for paint or adhesive application; and

(3) removal of surface irregularities such as grinding lines, burrs, etc.

The operation is more economical than pickling. It is an effluent-free process which can, under certain conditions, be substituted for pickling or chemical cleaning.

Mass finishing is a precisely controlled method of processing metal parts to remove burrs, sharp edges, tool marks, heat treat scale and to improve surface finish. It is generally termed "tumbling". In mass finishing, the parts are placed in a machine which imparts a revolving or vibrating motion between the parts and the medium. The medium is almost invariably water containing the burnishing compounds made up of abrasives, detergents, rust inhibitors, soaps, alkali cleaners or acidic salts.

(b) Chemical Surface Preparation

The more common chemical surface preparation techniques include vapour degreasing, alkali cleaning and secondary pickling, all designed to clean the metal surface for subsequent operations. Electroplating, for example, requires a very high degree of cleanliness of the metal surface. To accomplish this, a multi-stage cleaning procedure is usually followed.

The types of soil which may be encountered are:

> oily soils such as mineral oil-water emulsions, mill oils and oil-based rust preventives. (Normally these may be removed by alkaline cleaners.)
>
> semi-solid oils such as fats and waxes, and heavy rust preventive greases. These can be removed by heavy duty alkaline cleaners or by vapour degreasing.
>
> solids containing matter such as buffing compounds, pickling smut residues, partially decomposed greases, dirt and rust.

There are three types of chemical soil removal techniques employed to remove the unwanted matter from the metal surface, namely vapour degreasing, alkaline cleaning, and pickling and acid dipping.

Vapour Degreasing

Vapour degreasing consists of suspending the work in a container having a vapourized chlorinated solvent, usually trichloroethylene or perchlorethylene. The hot vapours condense on the cooler metal parts and dissolve the greases, oils and waxes. In addition to the vapour phase, most degreasers combine one or all of the following methods:

(a) immersion in boiling liquid;
(b) immersion in a warm liquid; and
(c) spraying with a clean solvent.

The vapourized solvent is condensed and re-used. When the solvent becomes contaminated, it can be recovered by distillation. Under no circumstances should the solvent be allowed to discharge to a sewer. The degreasing unit is equipped with a water-cooled cooling jacket or cooling coils to prevent loss of vapour into the air.

Alkaline Cleaning

Alkaline cleaning employs surfactant soaps and synthetic detergents and alkaline salts such as sodium hydroxide (caustic soda), trisodium phosphate, sodium polyphosphates, and sodium tetraborate (borax).

Methods of cleaning include soak tank cleaning or pressure spray cleaning followed by one or two stages of rinsing, with a still hot water rinse and running cold water rinse or a spray rinse to remove excess alkalinity.

Pickling and Acid Dipping

Pickling and acid dipping employ acids or strong oxidizing agents. Secondary pickling and/or acid dipping are utilized to produce a clean bright finish on the metal part. The operation removes smut on the metal surface produced during alkaline cleaning and the metal oxide coating or film produced during heat treatments of the metal.

Different formulations of pickling solutions and acids are used for different metals. Chemicals that can be used in various combinations in aqueous solutions include: hydrofluoric acid, nitric acid, sulphuric acid, phosphoric acid, acetic acid, hydrogen peroxide, chromic acid, sodium cyanide, sodium dichromate, citric acid, potassium nitrate, oxalic acid, potassium permanganate.

(c) Plating

The plating industry uses concentrated metal-bearing electrolytes, cyanides, alkaline cleaners and acids. It is a major source of contaminated effluents. Waste effluent streams result from running rinses, spills, leaks, and deliberate dumps. The metals most frequently encountered are chromium, nickel, copper, zinc, cadmium, tin and silver. Small amounts of palladium and other rare metals are also encountered.

Cadmium Plating

Most of the cadmium plating operations utilize a sodium cyanide-cadmium oxide bath. Some cadmium barrel-plating operations use a cadmium fluoroborate-cadmium metal bath.

Chromium Plating

A common formulation for chromium plating uses chromic acid (CrO_3)*. Decorative chromium plating provides a non-tarnishing film over a copper-nickel or a nickel base. Hard chromium plating is applied for functional purposes and the chief difference between it and a decorative film is the thickness of the coating.*

Acid Copper Plating

An acid copper bath usually contains copper sulfate and sulphuric acid.

Cyanide Copper Plating

Cyanide copper baths are used because:

- *(a) they can be used for plating steel and zinc base die castings directly, whereas acid copper requires a cyanide copper strike prior to regular plating; and*
- *(b) copper is plated from the cuprous or monovalent state, so that twice the thickness of copper will be deposited from the cyanide bath as from the acid bath for a given amount of electrical current.*

The formulation uses: copper cyanide, sodium cyanide, sodium hydroxide, sodium carbonate.

Alkaline Non-Cyanide Copper Plating

The bath for this non-cyanide copper plating technique is cyanide-free and is becoming more popular due to absence of cyanide resulting in a less severe waste disposal problem.

The bath contains copper pyrophosphate and potassium pyrophosphate.

Nickel Plating

Some typical nickel plating baths may contain some of the following chemicals: nickel sulphate, nickel chloride, boric acid, magnesium sulphate, ammonium chloride, phosphoric acid.

Palladium Plating

Palladium baths may contain palladium as disodium palladium tetrachloride or palladium tetra ammonium dinitrate or palladium chloride along with other chemicals.

Silver Plating

Silver plating baths may contain silver cyanide, copper cyanide, potassium cyanide.

Tin Plating

Tin plating baths may contain: stannous sulphate, phenol sulphonic acid, or stannous fluoroborate, metallic tin, fluoroboric acid (HBF_4), or potassium or sodium stannate, potassium or sodium hydroxide.

Zinc Plating

Zinc plating baths may contain (a) for alkaline zinc plating: zinc sulphate, sodium hydroxide, sodium cyanide plus other salts. (b) for acid zinc plating: zinc sulfate or chloride, sodium sulphate or chloride, magnesium sul-

phate plus other salts, depending on the plating properties desired. Zinc cyanide plating baths are also used.

(d) Special Surface Treatments

Stripping

Stripping of metallic coatings on rejects or on reclaim material is usually accomplished by immersion techniques. Among the chemicals that are used, depending on the metal to be stripped and the base metal, are: ammonium hydroxide, chromic acid, sodium sulphide, sulphuric acid, phosphoric acid, nitric acid.

Colouring of Metals

An almost unlimited variety of colours and shades may be applied to metals by heat treatment, chemical dips and electrolytic processes. A variety of acids, salts and polysulphides are used in the process.

Chromate Coating

Chromate coatings are produced non-electrolytically on zinc, cadmium, aluminum, copper, brass, bronze, silver and magnesium.

The purposes of chromate coating are:

for corrosion protection;
as final finishes;
as bases for paints and other organic finishes;
as decorative finishes.

The chromate chemical bath is an acid solution containing hexavalent chromium compounds and certain inorganic or organic compounds, known as activators.

(e) Phosphating

Phosphate coatings are transformations of metal surfaces into new surfaces having non-metallic and non-conductive properties. They are used:

(1) *to precondition surfaces to receive and retain paint and to protect surfaces against underpaint corrosion;*

(2) *to prepare surfaces for bonding with plastic coatings; and*

(3) *to improve corrosion resistance by providing a good base for waxes and rust-preventive oils.*

In phosphating, the phosphate combines with the metal component to form an integral metal-phosphate coating bonded to the base metal.

A phosphating cycle can consist of the following steps:

(1) *clean to remove soil*
(2) *water rinse*
(3) *water rinse*
(4) *zinc phosphate (or iron or magnesium phosphate)*
(5) *rinse water*
(6) *chromic-phosphoric acidified rinse*
(7) *dry off*

Aluminum Anodizing

Aluminum anodizing provides an oxide coating on aluminum parts as a protection against abrasive corrosion and as a base for paint bonding. The process is electrolytic and uses either chromic acid or sulphuric acid solutions to oxidize the surface layer to aluminum oxide. Typical cleaning and water rinsing procedures are used.

Painting

Ordinary spraying is probably the most common form of paint application. Here the paint is simply sprayed onto the metal parts as they move through a specially constructed booth. The back wall may be a water-wall using recirculating water from which accumulated paint wastes must be removed after a few weeks' use.

Dry booths using back-walls of straw have been developed. Here the straw is removed for disposal in a land-fill area or by incineration. Electrostatic painting results in a much more efficient use of paint and the water-wall can be eliminated. In this process, an electrostatic change is imparted to the paint which is then sprayed onto metal parts having the opposite electrostatic charge.

Mechanical paint stripping is done by sanding, scraping or burning. No liquid effluent is produced.

Chemical stripping is presently much more popular, more effective and more economical. Organic solvents, alkalies and acids can be used. Stripping baths accumulate the removed paint in the form of a sludge which must be removed. With continued use, the stripping baths becomes contaminated and at least part of the contents must be disposed of. The problem can be greatly reduced by allowing the tank contents to settle, decanting the clear supernatant liquid and then desludging the tank.

WASTE EFFLUENTS AND METHODS OF TREATMENT

Metal Manufacturing

(a) Steel

Wastes originating at an integrated steel mill include oils (both free and emulsified), suspended solids (such as mill scale), pickling acids, phenols, ammonia, cyanides and sulphides. Because of their nature and the quantity involved, these wastes are not suitable for discharge to a municipal sewage system. The basic steel manufacturing industry in Ontario has, therefore, constructed and is operating private waste treatment facilities. These are quite specialized and will not be discussed here.

(b) Foundry Operations

The principle sources of liquid waste effluents at foundries are:

Cupola waste gas scrubbing water for air pollution control purposes. The water scrubber removes solid particulate matter from flue gases. The scrubbing water may contain 5,000 ppm or more suspended solids and 500 ppm particulate iron. Dry dust catchers and electrostatic precipitators can be used in combination with wet scrubbers. This water cannot be discharged directly to municipal sewers and must be treated in some type of settling facility such as a clarifier, thus reducing the solids to more manageable levels. Settling alone will usually not produce a waste effluent of a quality acceptable for discharge into a storm sewer or watercourse.

Slag quench water. The hot slag is cooled by direct water quenching. Although most of the water and, indeed, all of the water if controlled properly, is evaporated, any excess may contain sulphides, particulate solids, and iron, and will be alkaline.

The cooling water used to protect the walls of the cupola. This water is usually uncontaminated since it does not contact the raw material or product and may be discharged directly into a storm sewer or watercourse.

Sand transporting and sluicing water. The molding sand is reclaimed for re-use. Modern sand reclamation methods are completely dry operations using no water and consequently produce no liquid waste. Many foundries still use wet slurrying methods for handling and transporting the sand. The burnt or waste sand slurry, besides containing large quantities of readily settleable solids, also contains certain organic materials and may contain phenol from the binders used in the casting operation. The waste, after pretreatment at the industry for the removal of solids, can be discharged into the municipal sanitary sewers for treatment of the organic and phenolic compounds. The best solution to the problem is the use of dry sand handling and reclamation procedures.

Metal Working

(a) Hot Rolling

The lubricating oil used in the machinery of the hot rolls is a major contaminant. The oil lost by leakage and during overhauls and maintenance of the machinery can be and often is a significant amount. It is best to prevent the oil from entering the waste effluent flow by using water cooled anti-friction bearings without oil lubrication.

(b) Descaling

Pressurized Water Spraying

The heat applied to the metal in hot rolling results in the formation of "scale" which is removed by high pressure water sprays. Most of the mill scale, being the oxides of the metal, can be removed from the water medium by settling in "scale pits" although the final effluent from a scale pit is not normally of a sufficiently high quality for direct discharge to a watercourse. Discharge to a sanitary sewer for final settling at the sewage treatment plant, if the volume of water is not a major consideration, could be acceptable. Filtration can be used as the secondary treatment method, removing both the remaining finely divided suspended solids and any traces of oil to produce a clear high quality effluent.

Pickling

In pickling steel strip, plate, or rods, two kinds of liquid wastes result: the concentrated spent pickling liquids, and the rinse waters. Both kinds of wastes are contaminated by dissolved iron salts (sulphates or chlorides) and by free acids, but in different concentrations. The iron content of the spent pickling liquid lies between 70,000 and 150,000 ppm, the acid content between 6 and 15 percent. The rinse waters have concentrations of between 500 and 1,000 ppm iron and a free acid content of 5,000 ppm.

The treatment of pickle liquor falls into two categories: non-regenerative and regenerative. The regenerative methods are preferred from a pollution control point of view since the potential contaminants are recycled for a productive use rather than simply being discarded.

Non-Regenerative

The pickle solution is simply neutralized with an alkaline chemical.

Lime

The chemistry is simple:

$FeSO_4$	+	H_2SO_4	+	$2Ca\ (OH)_2$
Iron sulphate formed by the reaction of the acid on the scale		Sulphuric acid		Lime added for neutralization

→	$Fe\ (OH)_2$	+	$CaSO_4$	$2H_2O$
	solid		solid	water

The reaction products, ferric hydroxide $Fe(OH)_2$, and calcium sulphate ($CaSO_4$), are relatively insoluble; after filtration the clear effluent is generally acceptable for discharge to a watercourse. Settling can also be used, but a difficult wet sludge disposal problem is presented. Small volumes (under 10,000 gallons per day) are easily handled in batch-treatment plants while greater volumes are processed more conveniently in a continuous operation. In either case, the pH must be raised to approximately 9.3 to precipitate the iron hydroxide.

The neutralization of hydrochloric acid pickling liquor with lime or any other alkali is not recommended because of the high dissolved solids produced by the reaction:

$FeCl_2$	+	$2HCl$	+	$2Ca\ (HO)_2$
iron chloride formed by the reaction of the acid on the scale		hydrochloric acid		lime added for neutralization

$$\rightarrow \quad \underset{\text{solid}}{Fe(OH)_2} \quad + \quad \underset{\text{soluble}}{2CaCl_2} \quad + \quad \underset{\text{water}}{H_2O}$$

Ammonium hydroxide has been used for neutralization but has the following disadvantages:

It is much more expensive than calcium hydroxide (lime), and the products of the reaction, ammonium hydroxide and sulphate, are very soluble. This results in a discharge of excessive dissolved solids and the nutrient ammonia to the watercourse.

NOTE

> *Neutralization using ammonium compounds is not recommended and, in fact, would not be approved by the Ministry unless other special circumstances absolutely required the use of the compound.*

Regenerative

The regeneration of sulphuric acid, (H_2SO_4), and hydrochloric acid (HCl), with the production of iron sulphate or iron oxide for sale offers certain economic advantages in pickle liquor treatment over the non-regenerative neutralization processes described above. These regenerative systems have relatively high initial capital costs but low operating costs. The neutralization systems, particularly the batch system, require only a low initial capital cost but a high operating cost.

(i) Sulphuric Acid Recovery

The pickling speed slows until the build-up of dissolved iron salts formed by the reaction of acid and scale reaches a level where further addition of fresh acid cannot provide acceptable pickling conditions. Cooling of the waste sulphuric acid pickle liquors precipitates out the dissolved iron as ferrous sulphate crystals and allows the pickling ability of the remaining acid to be renewed. Operation of the system is shown in Figure 12-2.

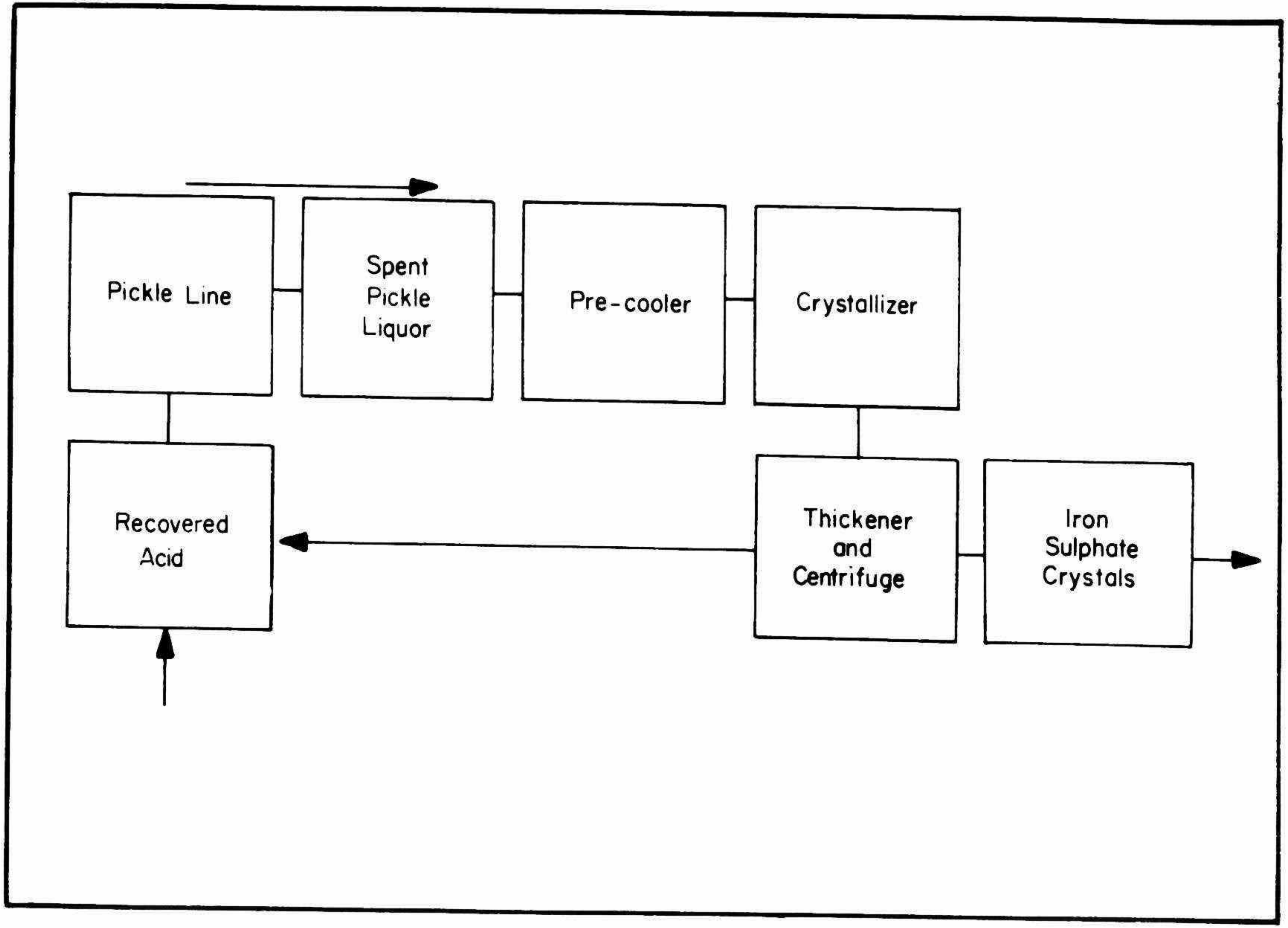


Figure 12-2
Flow Chart for Sulphuric Acid Recovery

Cooling of the spent pickle liquor to 40°F takes place in the precooler and crystallizer. Crystals are maintained in suspension and are passed through a thickener to a centrifuge which removes the dry iron sulphate crystals from the recovered acid. The recovered acid is returned to the pickle line.

In another system, the steel is pickled and passed to the rinse tank. The rinse tank is set up so that a set of sprays come on only when the steel is being withdrawn from the pickling bath. The contaminated rinse water is sent as make-up to the pickle tank and the acid strength of the pickle liquor is brought up to strength, leaving the iron concentration in the liquor as the only variable. When the iron strength increases to 9%, the liquor is sent to the Acid Recovery Plant where ferrous sulphate is crystallized out by cooling techniques and sold as a by-product. The reclaimed acid is re-used. This system eliminates the discharge of contaminated rinse water as well as reclaiming the pickle liquor.

(ii) Hydrochloric Acid Recovery

Regeneration of acid from waste hydrochloric pickle liquor employs fuel combustion to pyrolyze the iron chloride to iron oxide and hydrogen chloride gas, followed by separation of the iron oxide by-product and by absorption of the gas to reform hydrochloric acid. Almost 100 percent of the total chloride content of the waste pickle liquor is reconverted to hydrochloric acid. Operation of the system is shown in Figure 12-3.

The spent pickle liquor is concentrated in the pre-evaporator and is fed into a fluid bed reactor. In another system, the liquor is fed directly into a spray roaster. There the complete vapourization of the water and decomposition of iron chlorides into iron oxide and hydrogen chloride gas takes place at high temperatures (1500°F). The hydrogen chloride gas is driven off along with some iron oxide particles entrained in the gas stream. The solid particles are separated in a cyclone as iron oxide pellets. The gases, after cleaning and cooling in the pre-evaporator, are passed to an absorption column in which hydrochloric acid is reformed and returned to the pickle line.

In a hydrochloric acid pickling system, the production lines must be vented for employee health reasons. The

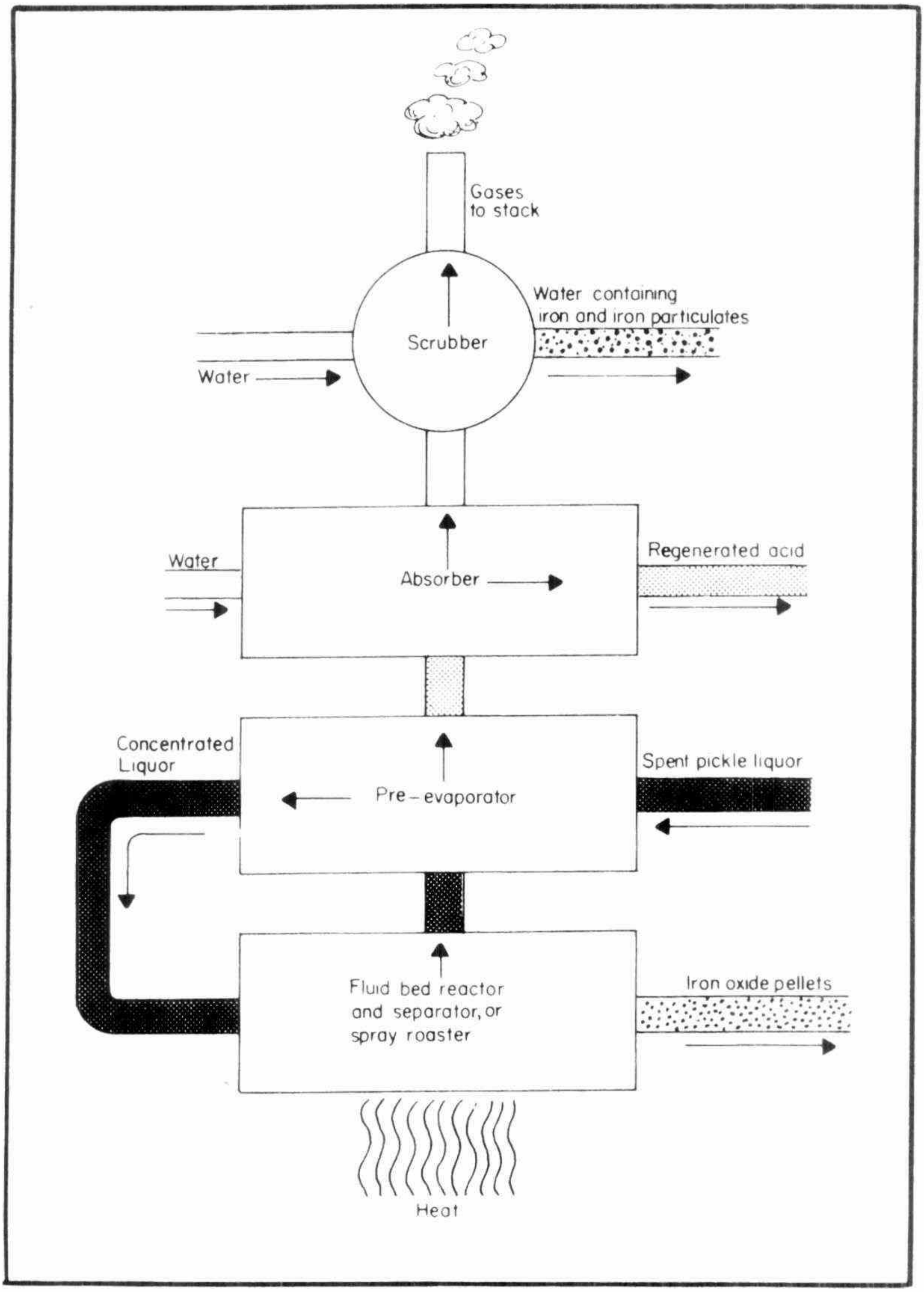


Figure 12-3
Flow Chart for Hypochloric Acid Recovery

vented hydrochloric acid vapour is water scrubbed, producing an acid waste effluent. In addition, the scrubber on the HCl Acid Recovery Plant system also contains certain quantities of acid and particulate iron. These wastes can be treated by neutralization, flocculation and settling, or filtration, although a certain amount of dissolved chloride compounds will still be discharged to the watercourse.

(c) Cold Rolling and Machining

Wastes from the cold rolling and machining operations are:

Oil-water emulsions used as coolant can be cleaned by filtering through paper or cloth, or by centrifuging, and are often recycled. However, depending on use and effectiveness of the reconditioning process, the oil eventually becomes rancid because of bacterial contamination and it must be discarded.

The oil adhering to the steel is removed by a pass through an alkaline detergent cleaning solution followed by water rinses. The spent cleaning solution then contains quantities of emulsified oil.

Leaks in the hydraulic systems and internal cooling systems of the metal-working machinery. The absence of sewer openings near the machinery and curbing around the machinery can prevent the oil from gaining access to the sewers.

The oil-soaked metal turnings and filings can be centrifuged to remove the oil and the metal can be returned as scrap. Often this procedure is not followed and the storage and disposal of the oil-contaminated metal turnings can present serious problems at the dump site.

The treatment of oil-water emulsions consists of two steps; (a) breaking of the emulsion and (b) removal of the separated oil from the water. Breaking of oil-water emulsions is particularly difficult since emulsifiers and detergents are used expressly for the purpose of ensuring that the oil and water phases do not separate.

Emulsion breaking is accomplished by the addition of salts, acids, heat, or a combination of these. In common use are calcium chloride, ferric salts, aluminum salts, sulphuric acid and hydrochloric acid. A combination of salts and acid is usually used in a treatment system. It is important to reduce the pH to below the free acid level or below pH 4, often down to a pH of 2. In a plant where pickling is also performed, some of the spent pickling liquor can be put to use in emulsion breaking.

Once the emulsion has been broken, the techniques used to remove free or unemulsified oils from water can be utilized. In virtually all cases, oil sludges accumulate on the bottom of the oil-water separators and must be removed, usually with a built-in scraper mechanism.

Alternatively, flocculating agents can be used and flocculated solids allowed to settle out for subsequent removal. Oily wastes containing paint wastes appear to be more amenable to flocculation and settling than to flotation.

The ultimate disposal of the collected oily skimmings and sludges can present a considerable problem. At a large automobile transmission manufacturing plant, the waste sludges, scum, and skimmings are dewatered in large "cookers" using indirect heating steam coils. Alum, used as the flocculating agent, is reclaimed by cooking the mass with sulphuric acid; it is re-used to flocculate the incoming wastes. Oil is also recovered. Other locations use large settling ponds in which the sludge has time to compact in the ponds from which it is periodically removed for land disposal. This is, at best, a questionable practice.

The best solution to the disposal of oily material would be re-using it as a fuel in the boilers of the powerhouse. However, this is not always feasible, either because the plant has no oil-fired burners, or the recovered oil is not of acceptable quality. Land disposal is not recommended because of the fluid nature of the material.

The solution to the problem appears to lie, for the present at least, in disposal by incineration. Oily sludges, whether or not combined with paint, solvent or similar wastes, can be disposed of by this method.

For an effective waste treatment system at any metal-working plant using oil or oil-water emulsions, the contaminated wastes must be segregated from all cooling water discharges and other uncontaminated flows. This is simply to provide a manageable oily water waste flow which will require a treatment system geared to the size of the oily water flow, not to the total water flow. Considerable economies are achieved by an effectively segregated sewer system.

The breaking of oil-water emulsions is probably best accomplished by a batch treatment system rather than by a continuous flow-through system. Each batch can be treated as unique, having its own properties and its own treatment procedure tailored specifically to that batch. In large metal-working and machining shops, there is considerable variety in the types of oils which are discharged in any given period of time. By using a batch system, simple lab tests can be run before full-scale treatment to determine the best treatment possible. Changes in the treatment procedure from batch to batch may include use of different chemicals to split the emulsion, different dosages, different retention times, or the application of heat. A batch system also lends itself more readily than a continuous system to a second treatment cycle if the results of the first treatment procedure are not satisfactory.

METAL FINISHING

(a) Mechanical Surface Preparation

Mechanical surface preparation procedures such as dry abrasive blasting produce no liquid wastes and are therefore preferred over pickling if quality specifications can be met by the operation.

Burnishing wastes must be treated for the removal of suspended solids by settling or, preferably, by filtration. Subsequent discharge to a sanitary sewer for further treatment of any organic soaps or detergents present is better than discharge to a storm sewer.

(b) Chemical Surface Preparation

Alkaline cleaning solutions must be treated for the neutralization of the solution and the removal of the soil, whether flotable greases or settleable dirt. Cooling of the solution in the settling chamber will often assist in congealing the greases and waxes present for removal by skimming from the top of the liquid.

The wastes from secondary pickling and acid dipping operations are treated as described in the section entitled "Pickling".

(c) Plating

To indicate the variety of wastes originating from a plant engaged only in metal plating, the following typical flow charts for four very common plating operations are presented. All four and more could be carried out at a given plant at any given time:

Copper Plating

alkaline cleaner	running rinse
5% HCl dip	running rinse
copper cyanide "strike"	running rinse
running rinse	copper pyrophosate solution
running rinse	hot still rinse
drying	

Nickel Plating

alkaline cleaner	running rinse
5% H_2SO_4 dip	running rinse
bright nickel solution	running rinse
soap dip	hot still rinse
drying	

Chrome Plating

alkaline cleaner	running rinse
H_2SO_4 dip	spray rinse
chromium solution	still rinse
mist spray rinse	running rinse
hot still rinse	running rinse
hot still rinse	drying

Zinc Plating

alkaline cleaner
5% H_2SO_4 dip
zinc cyanide solution
spray rinse
still dip
running rinse
drying

running rinse
running rinse
running rinse
HNO_2 brightener
running rinse
hot still rinse

From these flow charts, it is clear that the character and strength of plating wastes vary considerably from day to day and from plant to plant, depending on production. Following are some typical plating-waste concentrations:

	Plant A	Plant B	Plant C
pH	3.2	10.4	2.4
Cu, ppm	16	19	35
Fe, ppm	3	11	4
Ni, ppm	0	5	19
Zn, ppm	0	0	82
Cr, ppm	1	7	100
Cyanide, ppm	0.2	6	15

In all plating plants, the wastes originate from essentially the same operations. After the work has been immersed in either a plating bath, an alkaline cleaner, a strong acid, or a cyanide solution, the liquid material remaining on the piece must be rinsed off to prevent contamination of the succeeding chemical solutions. When the work is withdrawn from a particular bath, some of the solution from the bath adheres to the surface of the piece. This material, known as "drag-out", will contaminate the rinse waters with materials such as heavy metals, acids, and cyanides, which can range in amount from a trace to a value 50 times as large as that actually deposited on the work during plating. This drag-out value will depend on the shape of the piece being dipped, the amount of time the work is allowed to drain before going to the rinsing operation, and the viscosity of the solution. Other waste waters include those that result from batch dumps of spent acid, alkali cleaners, and cyanide solutions that have to be replaced at fairly regular intervals. The electroplating solutions are usually not dumped because of their high economic value.

Reduction of Waste Strength and Volume

The first step in solving the waste disposal problem (and sometimes all that is necessary to enable the plater to meet the local municipal sanitary sewer use by-law limits), is a lessening of the pollution load by reducing both the wastewater contamination and the volume. The methods used to achieve these objectives are:

(1) good housekeeping practices
(2) chemical recovery
(3) better process control
(4) process chemical substitution
(5) water recycle
(6) rinse water control

It follows that the smaller the volume of waste effluent to be treated, the more economical will be the required treatment system. This is particularly true for batch treatment systems. Because the rinsing operations produce the greatest volume of wastewater requiring treatment, rinsing should be performed with the best possible water usage. The usual methods advocated include:

(1) minimizing drag-out contamination by withdrawing the work slowly from the solution and allowing it to drain over the tank.

(2) using non-running reclaim rinses (drag-out tanks).

(3) controlling rinse water flows by conductivity cells.

(4) using multiple counterflow rinse tanks.

The first method is difficult to implement when dealing with manual operations and where employees are paid on a piece-work basis. The second method is almost always employed where drag-out recovery is profitable. Its method of operation is shown in Figure 12-4.

Losses from the plating solution due to evaporation and drag-out are made up from the contents of the still rinse tank.

Conductivity control is achieved by using a conductivity cell to monitor the amount of dissolved solids contamination in a rinse tank and to add water to the rinse tank only when the dissolved solids contaminant is above a pre-established level.

Counterflow rinsing consists of a system that utilizes several rinse tanks connected in series through which rinse waters flow in one direction while the work is rinsed in the consecutive tanks in the opposite direction. This reduces the volume of rinse water required by making better use of the water. The first rinse contains some contamination but is adequate to remove most of the drag-out from the metal piece. The third or final rinse is clean and therefore can adequately provide a final clean water rinse to the piece. In the system illustrated in Figure 12-5, the water is re-used twice, lowering the total water consumption.

Figure 12-6 shows, from an actual case, the reduction in waste volume made by installing double and triple counter-current rinses in place of single rinses.

Because of the low flow rates in a minimal water use countercurrent rinse system, agitation must be provided in each tank to provide sufficient mixing of the water to ensure effective rinsing. This is accomplished by blowing air through a perforated pipe placed horizontally near the bottom of the tank.

Other methods to reduce flow and contaminants include:

(1) installing a gravity-fed, non-overflowing holding tank or pond to contain toxic materials which could or would otherwise be lost to the sewer by power failures, line ruptures or other accidental spills.

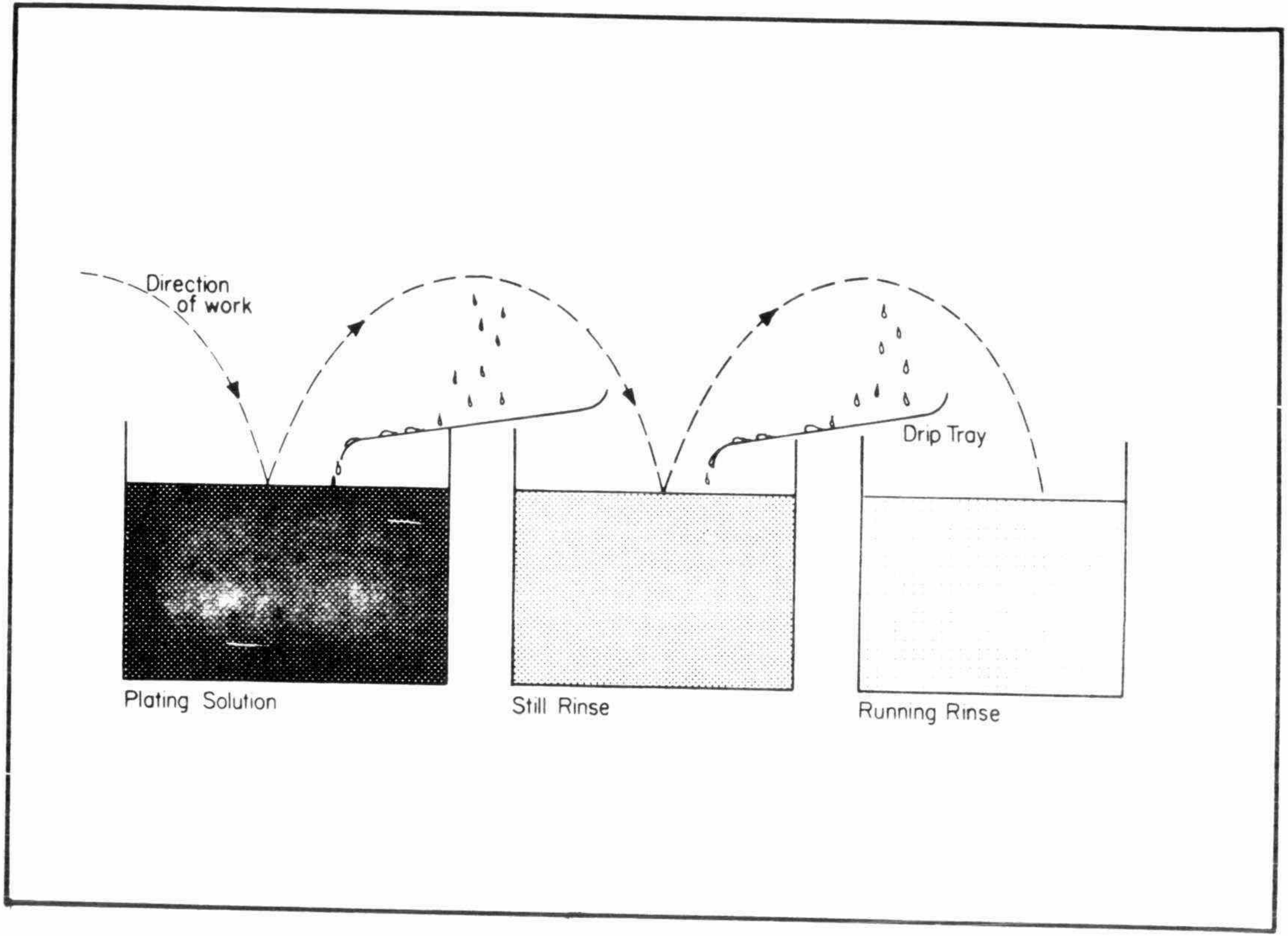


Figure 12-4
Recovery for Drag-Out

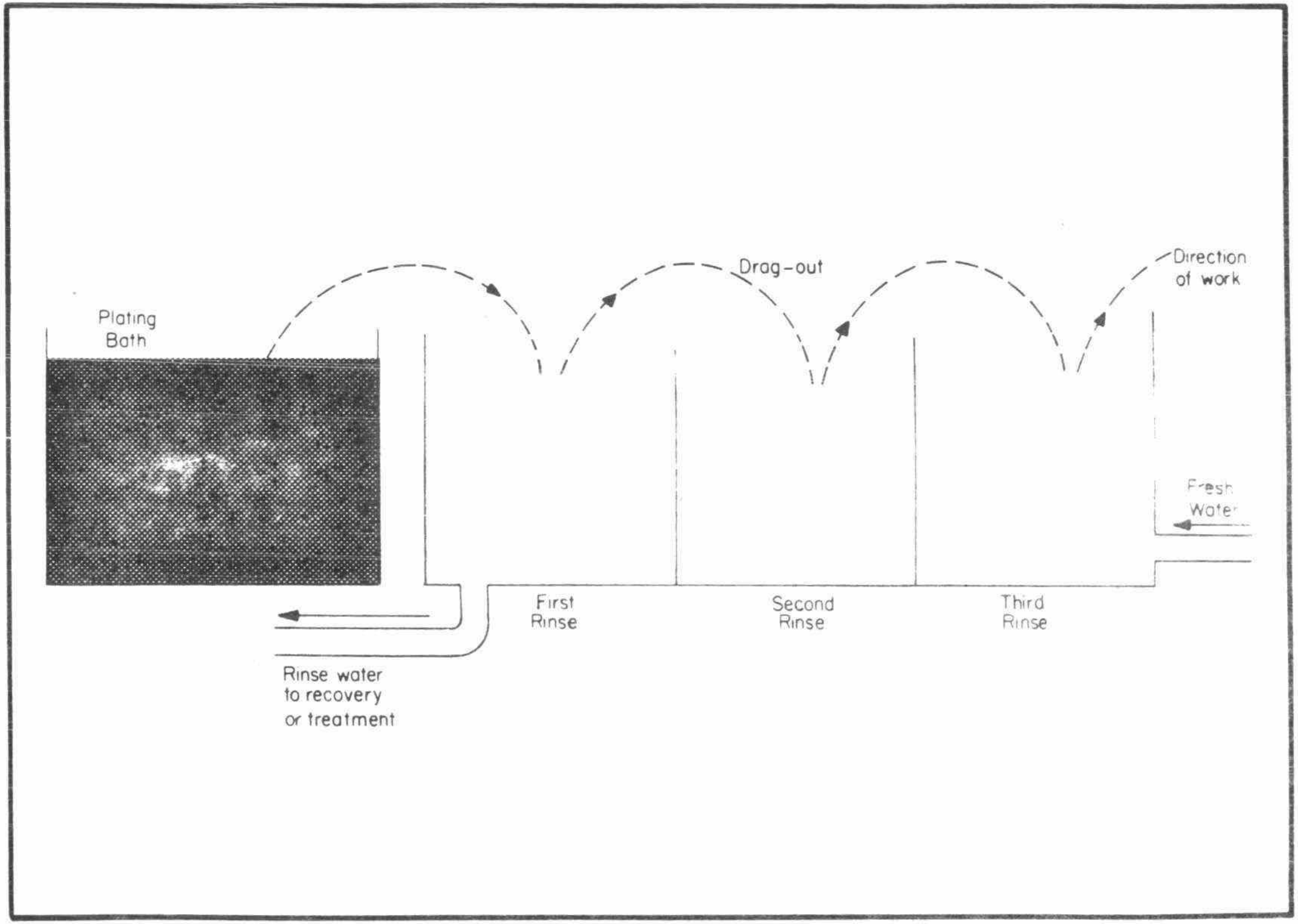


Figure 12-5
Countercurrent Rinsing

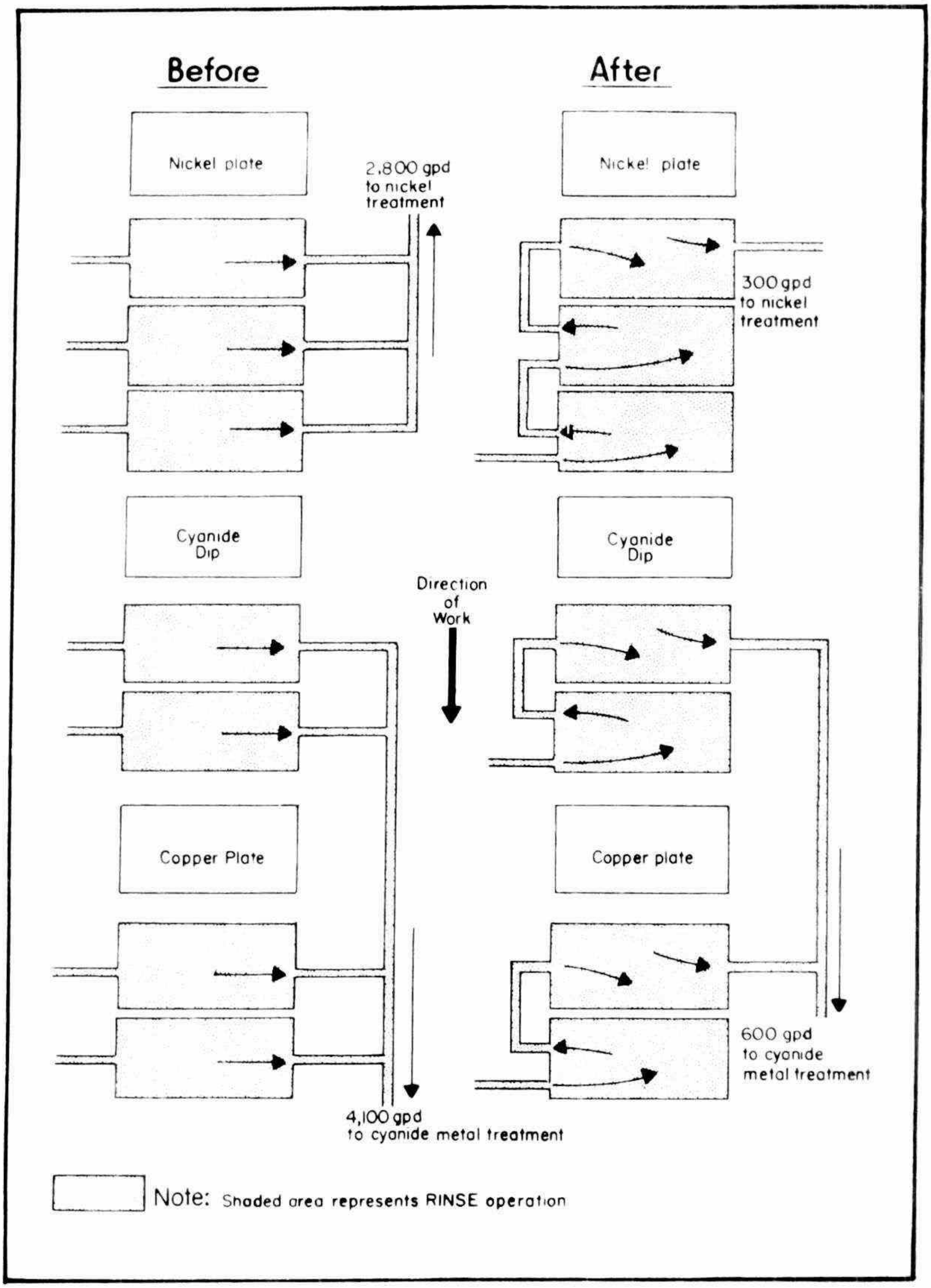


Figure 12-6
Use of Countercurrent Rinsing to Reduce Waste Flows

(2) eliminating breakable containers for concentrated materials.

(3) using drip trays and shaking mechanisms to maintain as much of the drag-out in the plating tank as possible.

(4) using spray rinses or high-pressure fog rinses rather than high volume running water rinses.

(5) reducing drag-out and spills by hanging surfaces as nearly vertical as possible. Rack with the lower edge tilted from the horizontal in order that the runoff is at the corner rather than at the whole edge.

Waste Treatment Systems

When everything has been done to minimize the volume of flow and contaminant concentrations, the treatment system can be selected. The chemistry of these systems can be complex. The briefest summary follows:

(1) Lime or caustic soda is used to raise the pH for neutralization of acids or precipitation of metals in the metal hydroxide form.

Example:

$$\underset{\text{lime}}{Ca(OH)_2} + \underset{\text{acid}}{H_2SO_4} \rightarrow \underset{\text{solid}}{CaSO_4} + \underset{\text{water}}{2H_2O}$$

$$\underset{\text{lime}}{Ca(OH)_2} + \underset{\text{nickel}}{Ni^{++}} \rightarrow \underset{\substack{\text{nickel} \\ \text{hydroxide} \\ \text{(solid)}}}{Ni(OH)_2} + \underset{\text{calcium}}{Ca^{++}}$$

Lime is less expensive than caustic soda but is more difficult to prepare and handle. Sludges produced using lime are generally more compact than sludges produced using caustic soda. Optimum pH values for precipitation of the heavy metals are:

	Optimum pH
Lead (Pb++)	6.3
Trivalent Chromium (Cr+++)	6.5 - 7.3
Copper (Cu++)	7.1 - 7.3
Zinc (Zn++)	8.3 - 8.5
Nickel (Ni++)	9.2 - 9.4
Cadmium (Cd++)	9.7
Aluminum (Al+++)	5.2

(2) An acid such as sulphuric acid is used to neutralize alkalies encountered in alkaline treatment and alkaline cleaning solutions.

(3) Cyanides are destroyed by oxidizing them with an agent such as chlorine or sodium hypochlorite at a pH of 11. The cyanide is converted to CO_2 and N_2 when enough chlorine is added, when the pH is properly controlled, and if the reactions are allowed sufficient time to go to completion.

The oxidation of cyanide to N_2 gas and carbon dioxide in the form of the bicarbonate is generally shown to occur in two stages as follows:

$2NaOCl$	+	$2NaCN$	$\rightarrow$	$2NaCNO$	+	$2NaCl$	(1)
sodium hypochlorite		sodium cyanide		sodium cyanate		sodium chloride (salt)	

$3NaOCl$	+	$2NaCNO$	+	H_2O	$\xrightarrow{pH\ 9}$	$2NaHCO_3$	+	N_2	+	$3NaCl$	(2)
sodium hypo-chlorite		sodium cyanate				sodium bicar-bonate		nitro-gen gas		salt	

Combining the two, we obtain:

$$5NaOCl + 2NaCN + H_2O \rightarrow 5NaCl + N_2 + 2NaHCO_3$$

An intermediate reaction in stage (1) above is the gas, cyanogen chloride (CHCl), which is at least as toxic as cyanide itself. The conversion of cyanogen chloride to the much less toxic cyanate by:

$$CHCl + H_2O \quad HOCN + HCl$$

is highly pH dependent and a pH of 8.5 to 9 or higher is essential for rapid conversion (in about 7 minutes). The destruction of cyanates to N_2 gas and to CO_2 in the form of the bicarbonate is also pH dependent and at a pH above 10 will not take place. At a pH of 9, it theoretically requires about 15 minutes. At a pH of 9.5 about 10 minutes are theoretically required. These are theoretical numbers and many other factors play an important role in the rate of reaction. However, it is extremely important to ensure that optimum pH values and adequate retention times are maintained in the reaction vessels.

(4) Hexavalent chromium is reduced to trivalent chromium under acid conditions using a reducing agent, usually sodium metabisulphite ($Na_2S_2O_5$) or occasionally SO_2 sulphur dioxide gas), or ferrous sulphate. The trivalent chromium so formed can be precipitated by treatment with lime. Because oxidation of cyanide requires alkaline conditions and reduction of chromium requires acid conditions, the two types of waste streams must be segregated from each other.

A batch treatment system is generally applicable to flows of 200 gallons/hour or less, although some treat up to 1,000 gallons/hour.

The oldest of treatment plants (and still in use) consists of a minimum of two tanks for each segregated waste stream, each tank of which is big enough to hold the effluent flow for one 8-hour shift. The first tank is allowed to fill and then the flow is switched to the other tank and an operator adds the treatment chemicals to the first tank. The tank is allowed to settle, the "clean" water on top is sewered, and the sludge is pumped out.

Sludge is held in tanks until removed to a disposal area. With the new regulations in effect for land disposal, disposal of this sludge is becoming more difficult. Other methods of treatment can reduce the magnitude of this problem and this is one other reason why the batch treatment method is less attractive than other more modern methods.

Continuous flow features are today incorporated in most large systems. Figure 12-7 shows a schematic layout of a typical waste treatment system for removing heavy metals, destorying cyanide and adjusting pH by an almost complete continuous flow method. These continuous flow systems require sophisticated instrumentation for measuring and controlling the treatment processes.

The final treatment stage shown in Figure 12-7 has, in the past, commonly been a large settling tank or chamber. However, certain metal hydroxide sludges, produced by settling fairly dilute suspensions of the metal hydroxide in water, are gelatinous and will not compact into a dense sludge. With the new regulations for land disposal sites now in effect, these sludges are no longer suitable for land disposal; it has become almost a requirement for new treatment facilities either to filter the settled sludge or to filter the dilute slurry effluent from the pH-adjusting tank. Filtration not only produces a dry filter cake that can be land disposed but it also provides a treated wastewater (of much higher quality than simple settling could produce) which can be recirculated in the rinse water or other water systems within the plant.

Specific Treatment Systems such as the Integrated Lancy System, incorporate treatment into the plating line itself. Parts coming from a plating bath enter a rinse containing an excess of the treatment chemicals. Two tanks and two stages are used for chromium treatment, but in other treatments only one stage is used. The system is shown schematically in Figure 12-8. The rinse, bearing the contaminant and the excess treatment chemical, constantly overflows into a large reservoir tank where the chemical reaction has time to be completed and the precipitated metals have time to settle. Reactants are also added to the reservoir tank. The work continues on into successive running rinses and any precipitated solids remaining in these running rinses are settled in a separate tank with the overflow going to the sewer. The treated wastewater is recycled from the reservoir back to the initial rinse tank containing the treatment chemicals.

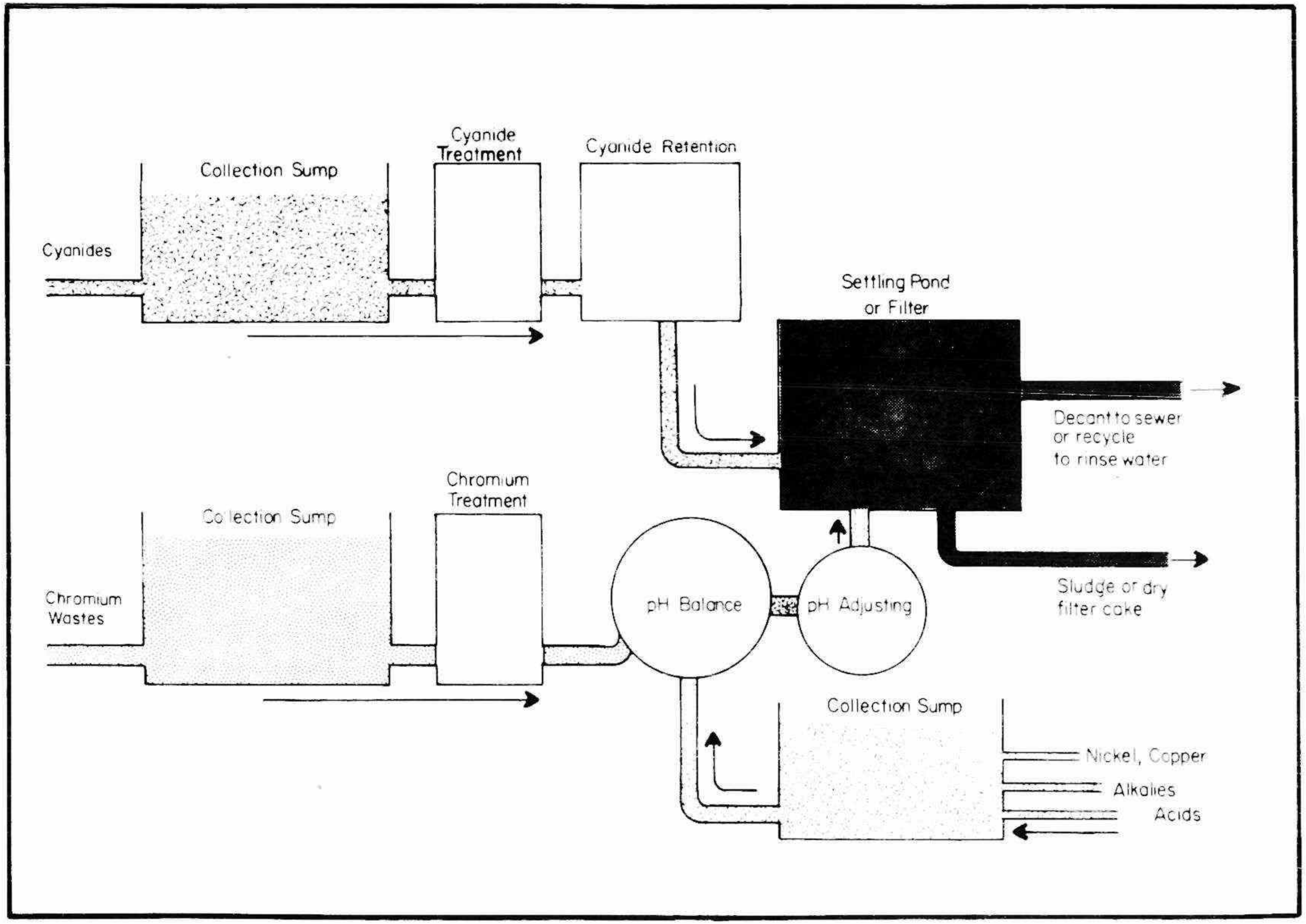


Figure 12-7
Continuous Flow Treatment of Metal Plating Wastes

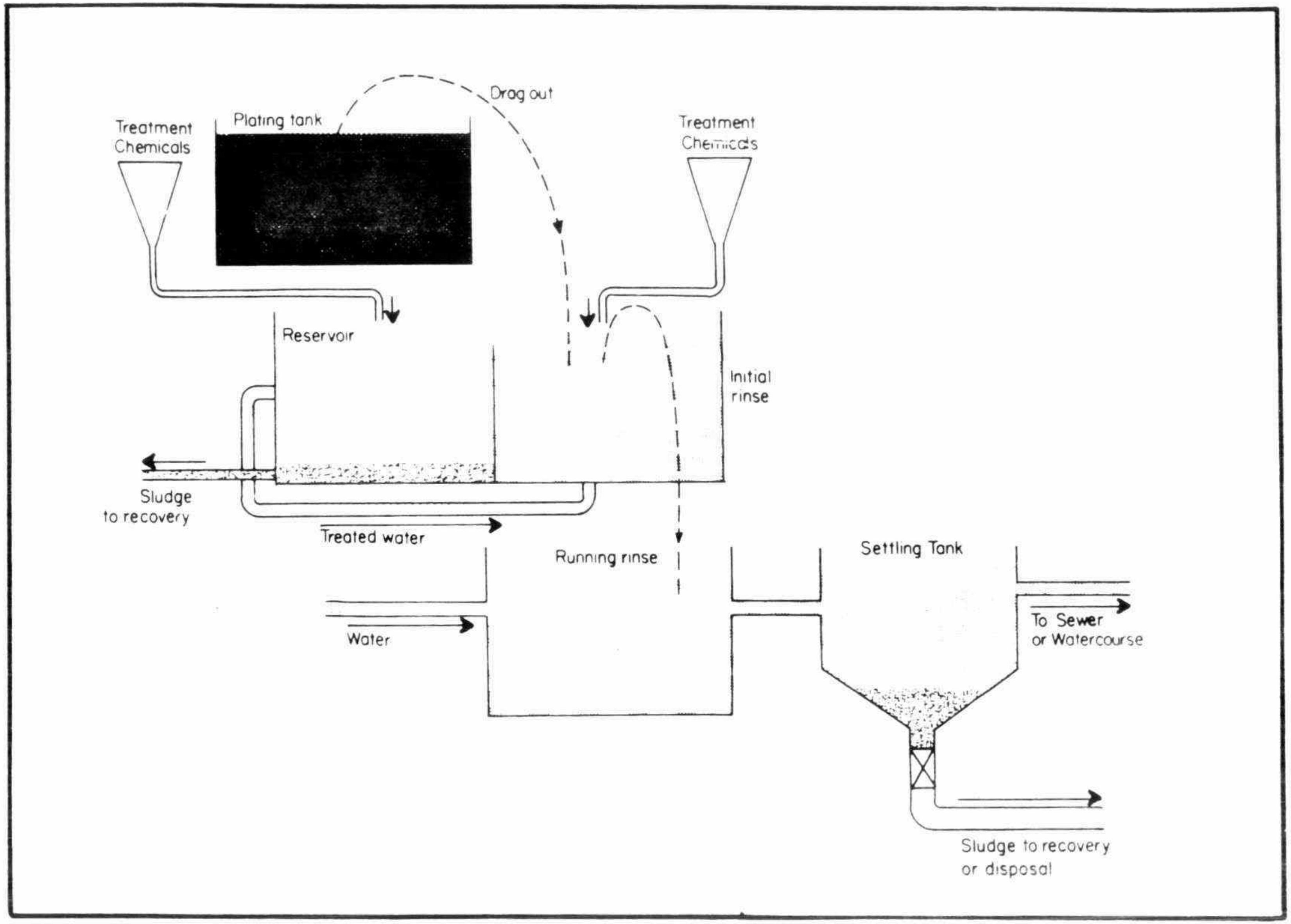


Figure 12-8
Integrated System Showing Recycle

In this system, the precipitated metals can be kept from each other in their own respective systems and the sludges are conditioned so that a high concentration, high density sludge of the particular metal oxide, hydroxide or carbonate, is collected in the treatment reservoir. Recovery of valuable metals such as cadmium, nickel and copper is not only easy but is practiced by all large users of this type of process. In some cases, this is sufficient to pay the operating cost of the system.

Recovery is an obvious way of getting something back from an otherwise unprofitable waste treatment investment. Unfortunately, recovery may be an expensive process in itself, or it may recover some undesirable or almost worthless material. In the plating industry, recovery involves recirculating water and recovering plating chemicals. Present day water and sewer cost increases are accelerating recovery approaches.

The conventional treatment for plating shop wastewaters is oxidation of cyanides with a chlorine compound and precipitation of heavy metals with sodium or calcium hydroxide. This procedure is followed by separation of precipitated solids by one or a combination of clarifiers, settling lagoons, pressure filters or vacuum filters. The above procedures are capable of complete cyanide destruction and metal ion removal, but the achievement of this requires the following:

(1) controlled efficient rinsing;

(2) correctly designed and installed treatment equipment;

(3) efficient and accurate operation;

(4) sensitive and robust electronic control instrumentation;

(5) first class mechanical and electrical maintenance;

(6) accurate laboratory control; and

(7) spill collection systems and fail-safe equipment devices.

All the above are seldom achieved together consistently, mainly because company management fails to recognize the strict requirements for effluent quality control.

Ion exchange is a method which will simplify operating procedures and which will produce a more consistent effluent quality. Ion exchange systems can be used in two distinct ways in plating wastewater treatment:

(1) concentration of mixed dilute rinse waters by factors ranging from 100-200 to 1, thus enabling waste treatment to be completed on a batch basis. Batch treatment is easier to control than continuous treatment and does not require complex control instrumentation. Sludges generated from concentrated solutions are easier to dewater and exist in relatively small volumes.

(2) by segregating individual plating bath rinses, i.e., nickel, chromium, zinc, copper, etc., it is possible to return regenerated solutions from the ion exchange columns, after concentration, to the original plating baths.

Ion exchange systems can offer the following advantages in all or part of plating wastewater treatment:

(1) metal recovery and re-use;
(2) supply of de-ionized water;
(3) lower capital and operating costs; and
(4) more reliable effluent quality control.

Ion exchange in plating waste treatment was originally used for recovery of nickel and chromium because of the high value of these metals. However, systems for mixed rinses including chromium, nickel, copper, zinc and cyanide can be operated satisfactorily and the regenerant solutions can be treated batchwise for cyanide destruction and metal precipitation. Following is a description of one such system now in operation. The characteristics of the rinsing wastewaters to be treated are:

	Average	Maximum	Minimum
Flow (IGPD)	41,000	53,000	33,000
Cu (ppm)	5		
Zn (ppm)	30		
CN (ppm)	20		
Ni (ppm)	1		

The mixed waste is passed through a series of three ion exchange columns:

Unit #1 - cation resin in the sodium form to remove heavy metals (regenerated by sulphuric acid).

Unit #2 - highly basic anion resin in the hydroxyl form to remove all anions including cyanide (regenerated by sodium hydroxide).

Unit #3 - a bed of cation resin in the hydrogen form to remove sodium and deliver de-ionized water to a final storage tank. (Resin becomes converted to the sodium form and will become Unit #1 in the next process cycle).

Wastewater from seven running rinse tanks flows into a common collection sump. The sump contains two pumps, each pump capable of handling the entire flow by itself.

The concentrated ion exchange resin regenerant solutions are treated by conventional methods to destroy cyanide, precipitate heavy metals and separate the sludge produced.

The de-ionized water is returned to the plating rinsing tanks. Figure 12-9 is a flow diagram of an ion exchange nickel-chromium treatment system.

Evaporative Recovery produces a pure distilled water and a solid residue consisting of the dissolved solids originally present in the water.

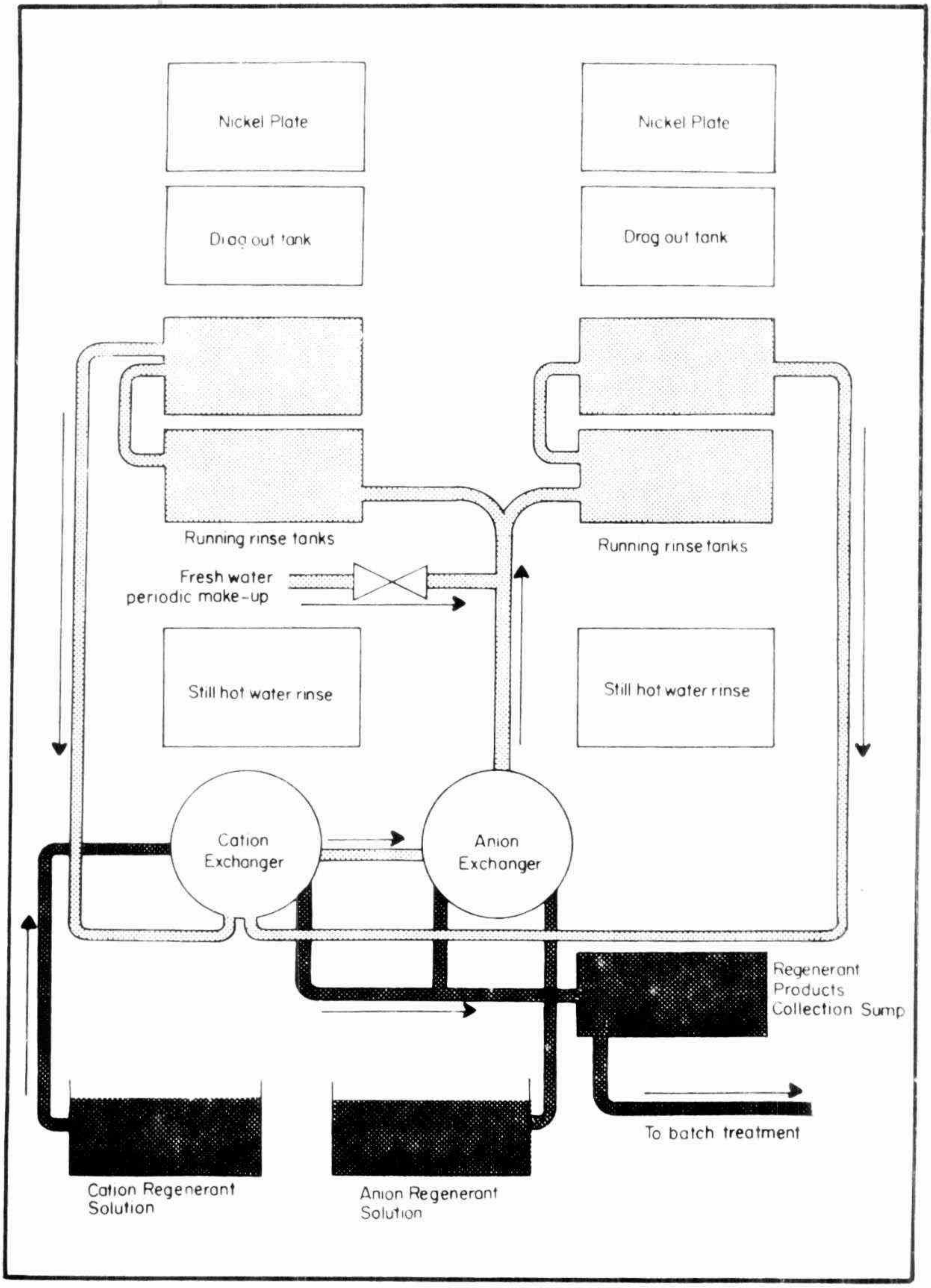


Figure 12-9
Ion-Exchange Treatment System

The principle of evaporative recovery of plating chemicals is an established technique. Figure 12-10 shows the most simple form in use in the plating industry.

The water in the drag-out tank is partially evaporated to the atmosphere to produce a more concentrated solution suitable for return as make-up to the plating tank.

Evaporative recovery is also a technique which can be used for recycling rinse water and recovering the plating solution. It is in use in Ontario and the technique will become more popular in the future not only in the plating industry but also in other industries generating wastes now considered economically untreatable.

Figure 12-11 shows the bare essentials of a "closed loop" evaporative recovery system.

Evaporative Recovery and Recycling is also practical and Figure 12-12 shows details of the system. Overflow from #1 rinse tank (most concentrated) collects in a holding tank and is drawn by vacuum into the main body of the evaporator. The solution is circulated through the shell side of the reboiler. Each pound of steam condensing in the tubues of the reboiler evaporates approximately one pound of water from the rinse solution.

A mixture of liquid rinse water and water vapour then re-enters the evaporator and is again recirculated through the reboiler. The water vapour, however, moves upward and passes into the shell side of the condenser where cooling water condenses it as distilled water. The distilled water is returned to the final rinse tank.

The liquid remaining in the evaporator becomes a more concentrated cyanide solution with each pass through the reboiler. When the desired plating strength is reached, it is valved over to the concentrate holding tank where it is available for make-up of the plating bath.

The capital cost of this system appears competitive with other systems.

Reverse Osmosis for the treatment of plating wastes streams is now under development in Ontario and appears

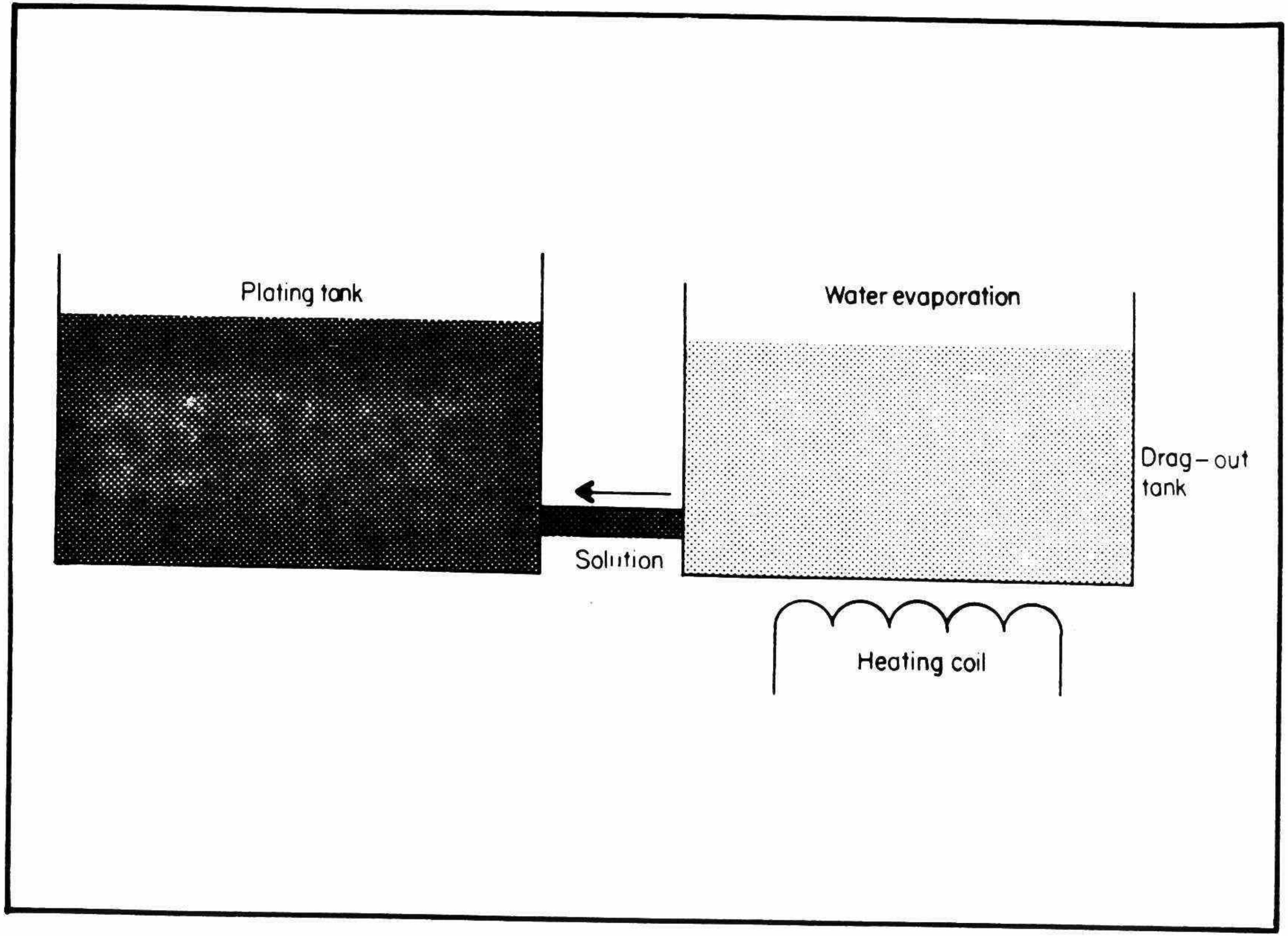


Figure 12-10
Evaporative Recovery of Plating Chemicals

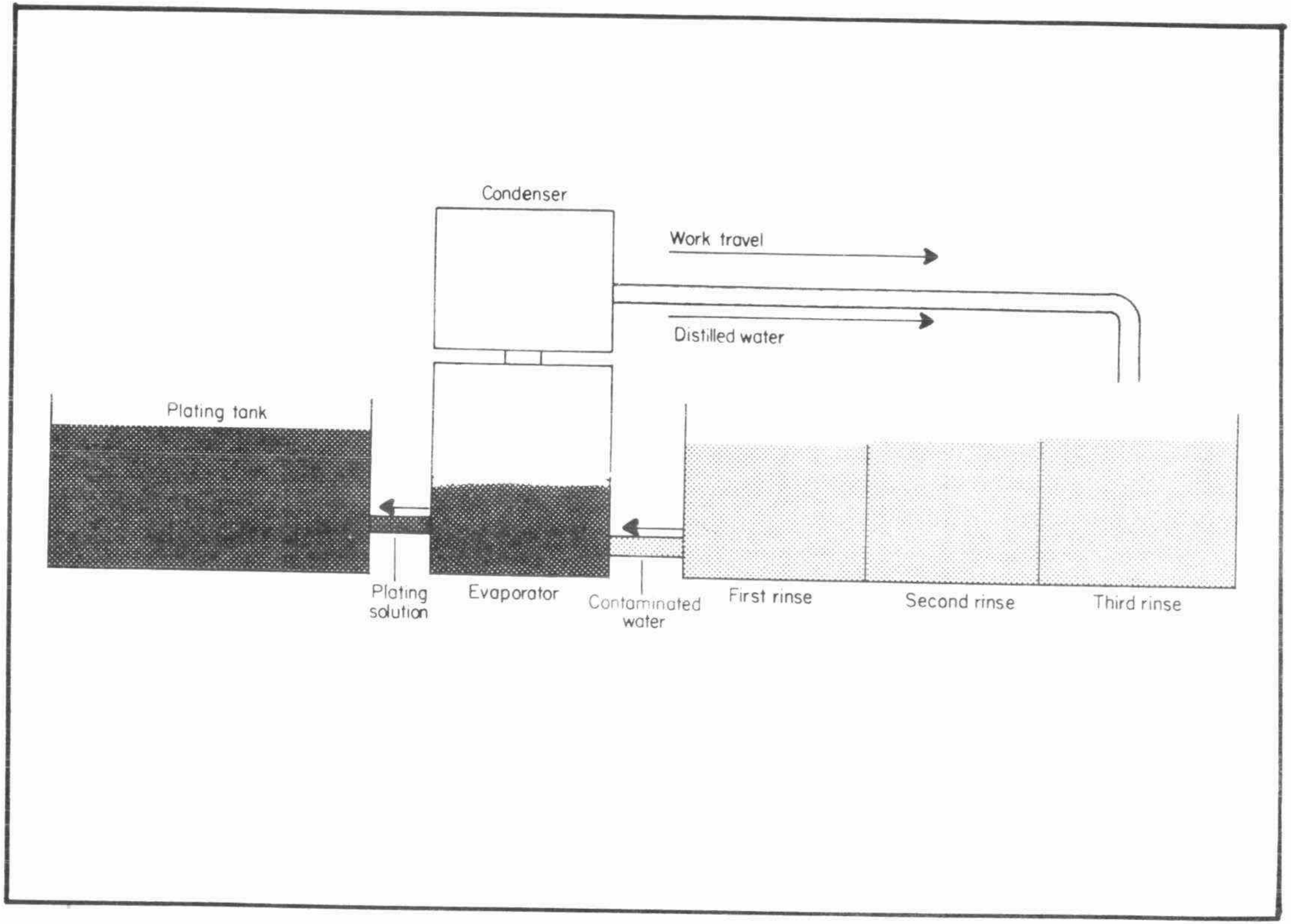


Figure 12-11
Evaporative Recovery and Recycling

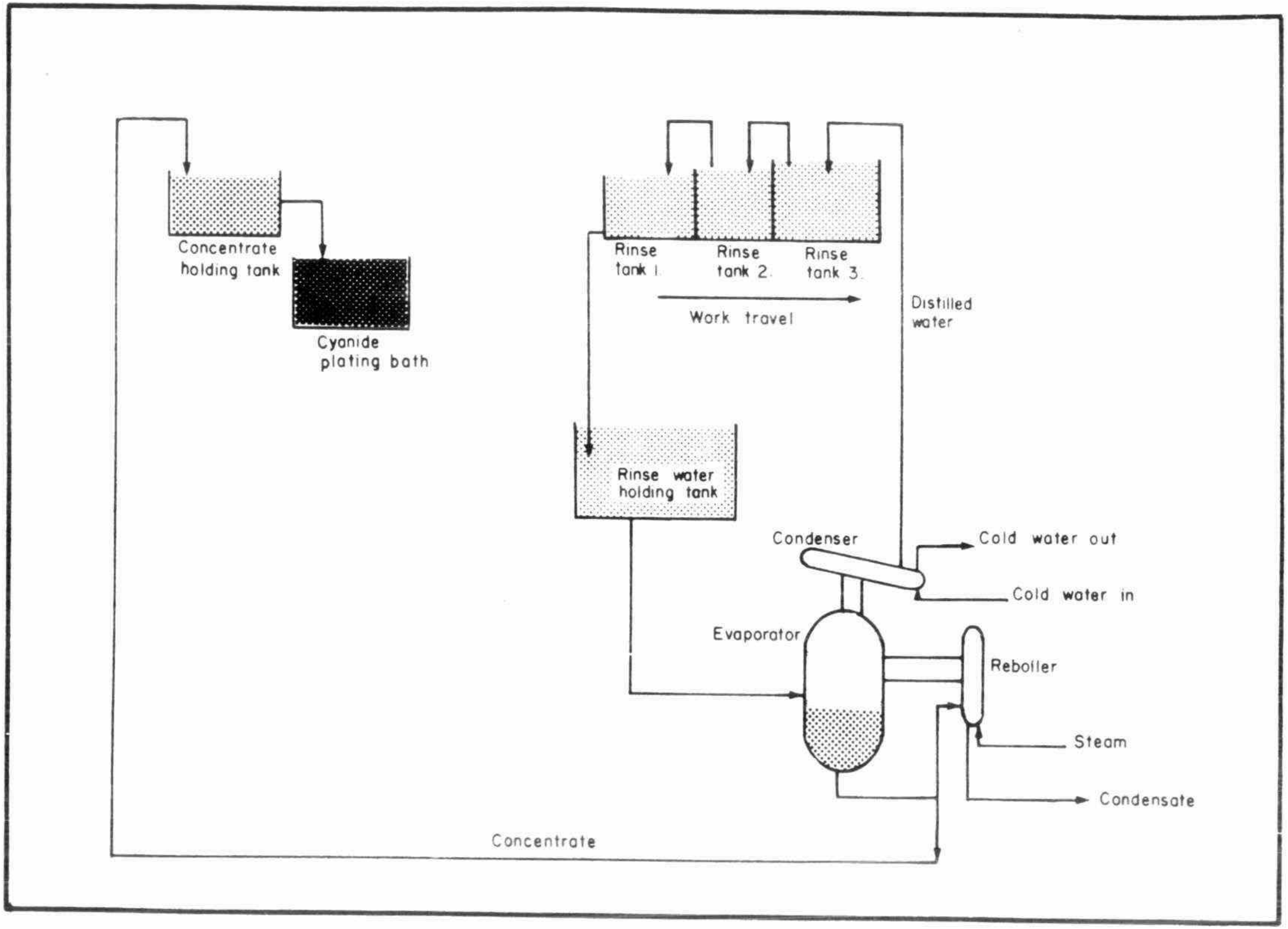


Figure 12-12
Single Effect Evaporator System for Cyanide Plating

to be feasible for nickel recovery.

The method has been given a field trial at a small plating shop. No change in plating quality occurred and nickel salt losses were practically eliminated. Calculated operating costs are much lower than the savings realized from recycling the nickel salt and pure water; the developer of the system is confident that reverse osmosis will play an important role in treating electroplating wastes.

Solids-Water Separation of the solids formed in conventional batch treatment systems must first be accomplished before final disposal, usually at a landfill site. The disposal of sludges containing 4% solids and 96% water on land is no longer considered acceptable by the regulatory agencies.

Settling in large lagoons is being used but has generally proven unsatisfactory and unacceptable. The ultimate answer appears to rest in recovery and recycling processes producing no sludge or minimal amounts of sludge. However, before this ideal is fully reached, a satisfactory solution can be achieved through filtration, either vacuum filtration or pressure filtration.

(d) Special Surface Treatments

The wastes originating from the variety of special surface treatments, such as stripping of metallic coatings, anodizing, chromating, phosphating, painting, and paint stripping, depend on the operation and the chemicals and metals involved. Almost invariably in all of these operations, cleaning with alkaline solutions is done before the primary operation and, with the exception of painting, water rinses are used following the primary operation. These associated operations contaminate effluents with the cleaning solutions and rinses in addition to periodic batch dumps of the primary treatment bath itself. In handling the wastes from these operations, all acids and alkalies must be neutralized, oils, greases and paint solids must be removed, and the metals must be precipitated out of the solution before discharge to the sewer or watercourse.

CONCLUSION

Based on experience in observing plating waste treatment procedures over the years, there are points which are important enough to bear repeating.

(a) Toxicity of Metal Finishing Solutions

Because of the very high strength and toxicity of many of the chemical solutions used in the metal finishing industry, it is extremely important to ensure that batch or slug discharges of these materials to a watercourse or biological sewage treatment plant do not occur. There are many cases where a discharge of a relatively small volume of toxic solution has wiped out the fish life of a relatively large stream. The biological floc of a municipal sewage treatment plant can be completely destroyed by sudden discharges of toxic materials to the plant. This is particularly true in the smaller municipalities. Pumps and other critical pieces of treatment equipment must be duplicated and available as stand-by facilities for emergency use as required. Use emergency holding tanks or large emergency impoundment basins, if land is available. Valve failures, pipe connection leaks and cracks in concrete trenches are common and must be guarded against by protective curbing and by specially designed sewer systems and drainage patterns so that toxic chemicals cannot reach the normal wastewater or storm water outlets. A treatment system using gravity to direct the flows is preferred to one requiring pumping. Automatic pH analyzers connected to alarm systems are essential to a good waste control program. Closely related to these measures is a training program for plant employees regarding the proper use of manufacturing equipment and plant drains and emphasizing the necessity to quickly stop spills of any sort if and when they do occur. Such a training program is an essential part of any good waste control program.

Frequent unexpected visits by municipal inspectors to industries on the municipal systems will encourage the plant to minimize the potential for spills.

(b) Monitoring of Waste Effluents

Every industry should be required to monitor the quality of its waste effluent, just as it would monitor the *quality of its product. If such a monitoring program is in effect, the industry has an incentive to maintain or improve the waste effluent quality.*

The use of certain simple paper tests for cyanide and the heavy metals is not recommended for effluent monitoring purposes. Time and again, it has been found that misleading results have been produced, and in fact, fish kills due to cyanide have occurred while the plant effluent was being monitored by one of the paper tests, giving results that showed the absence of cyanide. In one particular case, the paper used was simply not sufficiently sensitive to the low concentration of cyanide which can kill fish. A plater thinks in terms of percent solutions in his production facilities; it is difficult for him to think in terms of parts per million. A 1% solution (which is a weak solution to a plater) contains 10,000 ppm; 1 ppm cyanide will kill fish.

CHAPTER XIII

BULK LIQUID STORAGE

Since most materials are environmentally hazardous if released in quantity, bulk liquid storage facilities must be included in a program for municipal control of industrial wastes.

Some of the liquids commonly stored in bulk are: gasoline, nitric acid, ammonia, bunker fuel oil, trichloroethylene, ammonium hydroxide, sulphuric acid, alcohol, benzene, glycerine, asphalt, hydrochloric acid, caustic soda and others. The variety of materials is so great that losses involve a large number of clean-up techniques, often difficult and costly.

A liquid stored in bulk can cause no pollution problems as long as it remains properly contained. Containment, therefore, is the vital key to control of pollution by liquids stored in bulk. Retention of a spilled liquid as close as possible to the point of spillage is mandatory. Consider the following example. A tanker vehicle carrying gasoline is involved in a traffic mishap and gasoline leaks from the tank. Invariably, the first action of those responsible is to flush away with water the spilled material, thereby "eliminating" severe fire hazard. However, water and gasoline do not mix and by flushing, the fire hazard has merely been removed from a purely local area and has been spread through perhaps many miles of sewers. Not only has the hazard been spread, it has actually been increased since persons remote from the site of the spill are exposed to the gasoline - but are unaware of its presence. In addition to the hazard to human life, there is the damage to the environment which must be considered. Therefore, no matter the nature of a spilled liquid, it must be retained as close as possible to the site of the spill.

It is, of course, very easy to contain spills from a static installation. It is much more difficult to provide the same protection in the case of mobile tanks. The methods used in containing spills from tanker vehicles depend so much upon the circumstances of the spill that they will not be discussed here.

The following applies to stationary tanks.

When a material is spilled, there are two ways by which it may tend to move away from the spill site: either on the surface of the ground or below the surface. In many cases, both will be of concern. It is desirable to eliminate the possibility of spilled material soaking into the ground; the first step towards containment, therefore, is to ensure that the site is provided with an impervious surface. If this is done and a spill occurs, the liquid, being unable to soak into the ground, will tend to flow away towards the low point.

The second step towards containment is to ensure an impervious dyke or wall around the perimeter of the site, high enough to enclose more than the volume of the largest tank.

When these two steps have been taken, any liquid falling within the impounded area will be trapped and may then be removed for proper disposal. Of course, rain falling within the area will be trapped, but can be removed by pumping to the outside of the dyke or wall where it may flow into the storm sewers. If rain water becomes contaminated while within the impoundment, it must not be disposed of by pumping to the storm sewer system. The drainage within the impoundment should allow all liquid to flow to a small sump from which it can be pumped out for treatment and/or disposal. A common method of allowing rain water to escape from an impoundment containing tanks in which petroleum products are stored, is through an oil separator at the lowest point. However, this type of system is less than satisfactory due to its inability to handle widely varying flow rates (for example, during a heavy rain storm) and consequently, any contaminants previously trapped are flushed away.

For this reason, removal of liquid from within the impoundment should be by pumping only. In the case of a liquid which floats on water, the pump intake should be at the bottom of the sump and pumping should cease before the floating layer nears the intake. In the case of a liquid which mixes with water, pumping to the sewer is not permissible without adequate treatment of the material. Pumping into tank vehicles for transportation to an ultimate disposal site is of course allowable.

From time to time, liquid will be added to and withdrawn from a tank. Precautions must be taken to ensure that pollution is not caused by leaks from pipes, pumps and other equipment. All equipment, where possible, should be within the containment area or should be drained into it. As an example, if liquid is transferred between a road tank vehicle and a bulk installation, an impervious pad should be constructed for the vehicle to stand on while the liquid is being transferred. The pad must be graded and drained so that spilled liquid is retained or flows into the impoundment area.

The simple retention systems described may be implemented where tanks are above ground and are not of very large volume. Very large tanks, for structural and economic reasons, must rest upon the ground; usually a sand base is prepared before placing the tank. Leakage from the tank bottom, therefore, is not immediately apparent as the liquid soaks into the ground. The best defence against such an occurrence is exhaustive testing of the tank before it is put into service, but, even where this is done, leaks may occur. In such cases, retention is almost impossible to achieve and early detection of a leak is vital. Probably the most economical means of detecting a leak is to install test wells at strategic points around the site. The wells are inspected regularly for indications of the presence of the material stored in the tank.

An impervious surface may be laid over the remainder of the site and a dyke constructed within the impoundment to enclose a volume greater than that of the largest tank. As before, any liquid falling within the dyked area is pumped out for proper disposal.

Where tanks are underground, a system of test wells should be installed as previously described. Ideally, no tank should be buried; instead, a pit should be prepared, of concrete or other structural material, big enough to allow inspections around the tank. No drainage is allowed from the pit and any accumulation of liquid is removed by pumping. The pipes leading from such tanks are above ground. If that is impossible, the pipes are laid in a liquid-tight trough which drains to the tank pit. Precautions for transferring liquid between the tank, and (for example) a road tank vehicle, are required as already described.

Apart from the steps to retain spilled liquids, each site should have a supply of material and equipment for use when a spill occurs. For example, if hydrochloric acid is spilled, a supply of water must be immediately available for dilution and a quantity of alkali for neutralization. In case of a highly flammable liquid spill foam generators should be available. Equipment and procedures, approved by knowledgeable and competent personnel, are required if serious accidents are to be avoided when dealing with spilled materials.

The measures described will successfully prevent spilled liquids entering sewer systems, but prevention of spills should be a priority. Maintenance of all equipment and training of employees are extremely important. Conscientious and knowledgeable employees are the best insurance against pollution from bulk liquid storage installations. Education programs for the management and staff of those companies where conditions are less than satisfactory may have to be undertaken.

The following will result in fewer cases of pollution from bulk liquid storage facilities:

(1) No buried storage tanks;

(2) No underground pipes;

(3) An impervious surface at storage areas;

(4) A dyke or wall around storage areas;

(5) Properly designed loading and unloading facilities;

(6) Supplies and equipment for dealing with spills; and

(7) First-class maintenance and employee training.

CHAPTER XIV

DRUM RECONDITIONING

INTRODUCTION

Although drum reconditioning does not constitute a major industry in Ontario, it does produce strong wastes that require treatment prior to disposal. This industry takes used steel drums and cleans them so that they may be re-used. Used drums may have contained, for example, varsol, pesticides, paints, varnishes, oil and greases, etc., and the resultant wastes from cleaning them contain traces of these products as well as a quantity of the cleaning chemicals. Serious pollution problems can result if these wastes are discharged indiscriminately.

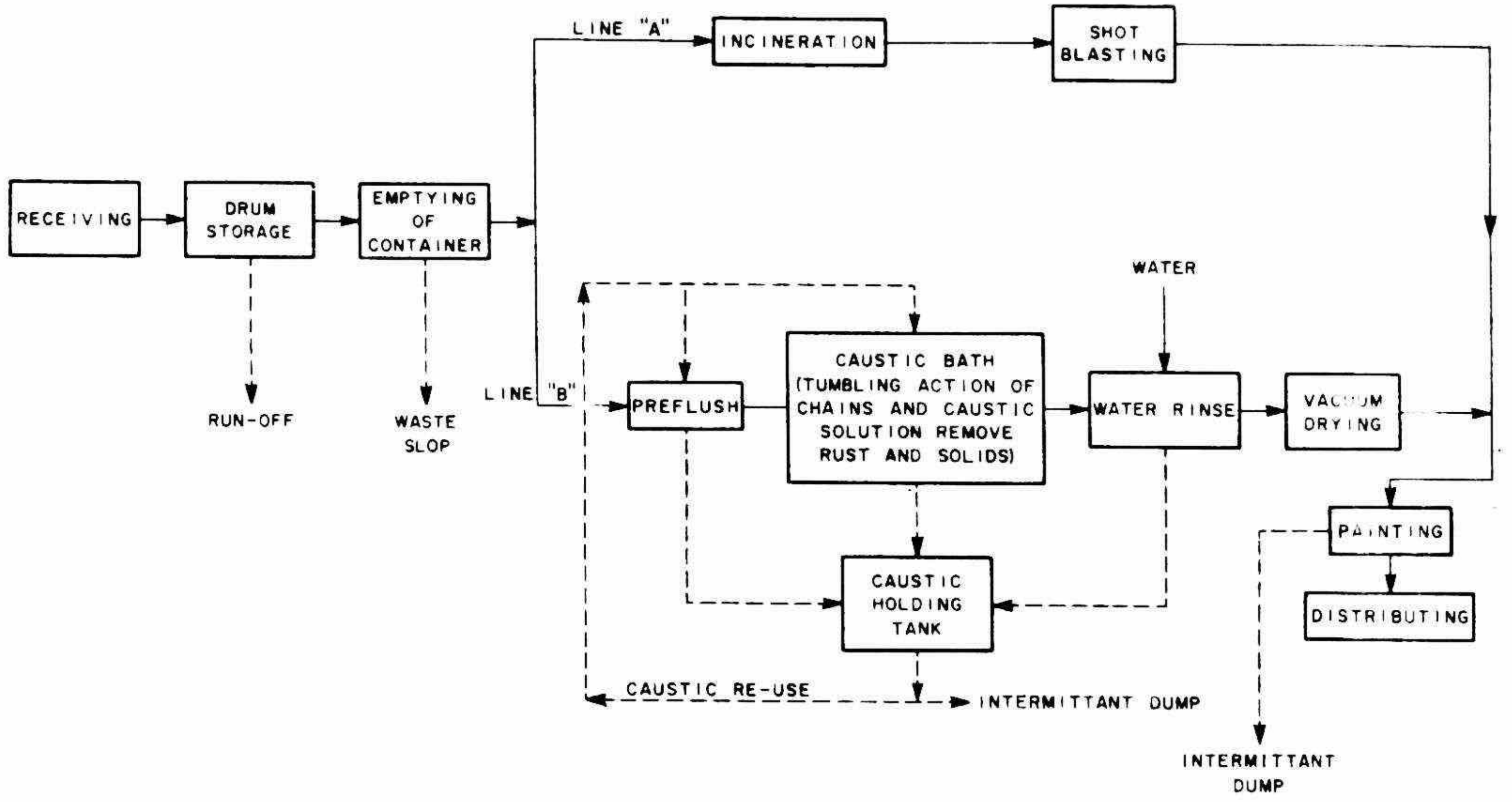
PROCESS OPERATIONS

The drums are received by truck or rail and are stored outside prior to processing. Residual drum contents are emptied, normally by hand, into a sump and the drums are passed on for cleaning. The cleaning operation consists of various washes such as a primary wash, caustic wash and water rinse. After drying, minor mechanical repairs are made as required and the drums are painted. The lids are passed through a similar operation and are also painted prior to shipment. A general process flow sheet of the operation is shown in Figure 14-1.

SOURCES OF WASTES AND DISPOSAL

Runoff from the storage pile tends to pick up residual materials spilled from the drums, creating a potential source of pollution. Drum storage areas require the construction of concrete pads to prevent materials from seeping into the ground and gaining access to groundwater. Also, the areas should be dyked to collect runoff and convey it to a suitable treatment system.

Before entering the plant for cleaning, the drums are emptied to remove the residual materials. These "slops" are usually collected in a sump and are hauled away for suitable disposal. Because of the variety of products contained in the drums, deep well injection of the slops



LINE "A" - OPEN HEAD DRUMS (ONE END OPEN) FOR SUCH PRODUCTS AS PAINT, GREASE, ADHESIVES.

LINE "B" - CLOSED HEAD DRUMS (CLOSED EXCEPT FOR OUTLET PORTS) FOR SUCH PRODUCTS AS OIL, SOLVENTS, LIQUID DETERGENTS

COMMENT - SULPHURIC ACID SOMETIMES USED INSTEAD OF CAUSTIC SODA IN CLEANING OPERATIONS.

Figure 14-1
Flow Chart - Drum Reconditioning

is probably the best method of disposal.

The caustic preflush and caustic wash water will pick up any materials left in the drum. Since these wash waters may contain materials toxic to aquatic life, treatment is required before they can be discharged to a watercourse. Treatment prior to sewer disposal is also necessary, since the waste may "shock-load" a sewage treatment plant and create operational problems.

The caustic solutions are disposed of periodically when spent. These solutions normally require neutralization and clarification prior to disposal. Separation of oils and greases may also be required.

The final water rinse will be contaminated with residual caustic and will exhibit a high pH. Again, neutralization is required before the waste is disposed. However, the final rinse water can be re-used as make-up in the cleaning operations.

Painting of the drums and lids is normally done in a water wall paint spray booth. A water curtain catches the paint droplets and prevents an excessive build up of paint on the booth walls. This water is normally recycled. Paint solids are coagulated and skimmed off at regular intervals. The water itself is occasionally dumped to the sewer and will require suitable treatment.

WASTE CONTROL

The volume of waste produced should be controlled and reduced to a minimum. If drums are allowed to drain longer than usual, less residual material is transferred to the wash water, thereby reducing the waste strength. The use of high pressure sprays in place of running rinses could reduce the volume of wash water which should be recycled whereever possible.

Once in-plant control measures have been implemented, wastes must be treated to produce an effluent acceptable for disposal. Such treatment might include one or more of the following:

- pH adjustment;
- oil separation to remove oil, grease and surface scums; and
- clarification to remove solids and metals precipitated during pH adjustment.

Disposal methods might include:

- deep well disposal;
- land disposal of solids;
- haulage of strong liquid wastes for commercial treatment or disposal to a deep well; and
- incineration.

CHAPTER XV

READY MIX CONCRETE

Concrete is manufactured by mixing various percentages of aggregate, cement and water. Aggregate can take the form of coarse stone, fine stone, or sand, depending on the end use of the product. The aggregate is kept in stock piles and the cement is stored in a silo. On occasion, chemicals of various types are added to make specific kinds of concrete.

In late 1971, staff of the Industrial Wastes Branch met with representatives of the Ready Mix Concrete Association of Ontario. It was pointed out to the members that the practice of disposing of truck washout wastes into rudimentary settling tanks that overflow to adjacent watercourses could no longer be tolerated. It has been the practice of all ready mix companies that when a ready mix truck returns to the plant at the end of the day, or in some cases when a change in grade of concrete is to be carried in the barrel mid-way during the shift, the driver disposes of the returned concrete in an isolated location on the plant property and then fills the barrel on the truck with 200 to 300 gallons of water. The barrel is left turning and the contaminated water is then discharged into the settling tank. Lab analysis of this discharge has revealed that it is highly alkaline, having a pH in the range of 12.5 to 13.5, and having a high suspended solids concentration of 100 to 300 ppm. As the Province's guidelines are a pH of lower than 9.5 and a suspended solids concentration of less than 15 ppm, these wastes obviously must not continue to be discharged in this haphazard manner.

Waste Treatment

Several alternative methods for treating the wastes include neutralizing the alkali by adding sulphuric acid, carbon dioxide, sodium bicarbonate, waste smoke-stack gas or natural gas, to the wastes.

The use of sulphuric acid is unacceptable because it is very difficult to control the final pH in the range of 5.5 to 9.5, and the other chemicals are even less satisfactory.

Two other methods were considered and discarded: spray irrigation, which would require the availability of suitable soil and extremely careful spray control, and trucking the wastes to a disposal site, which is prohibitively expensive.

One additional method, the re-use of the contaminated wash water, is the most acceptable. With the re-use method, wastes are discharged from the truck into the first of a series of settling tanks where the suspended material settles and the clarified liquid overflows into the adjacent tank. An ideal settling time has been determined; this is used when calculating the size of the settling facility. The clarified effluent is directed into a holding tank where it is pumped back to the truck wash-rack to be used to rinse out the next truck.

An automated adaptation of this method of treatment has been put into use (similar to the Jadair "Redi-Wash" machine). The trucks are filled with re-use water, backed up to the machine and the liquid is dumped into the tank. The machine is equipped with scrapers which continuously remove the cement fines while the settled aggregate is removed at a different location on the machine. One company has been successful in reclassifying this aggregate into its compounds and stockpiling the material for further use in various grades of concrete.

Winter operation of the "re-use" treatment method (both automated and the simpler settling tanks and return pumps) requires heating so that piping and controls do not freeze. Some companies have erected buildings to house their equipment and one company piles heated sand against one wall for ample heat.

Water pollution by the Ready Mix Concrete Industry is caused by improper disposal of truck washing wastes. This problem may be overcome, either by neutralization and settling of the wash water, or by settling and re-use of the wash water. The latter is preferred because there is no pH problem. In addition, the re-use system provides aggregate which, after classification, may be recycled.

CHAPTER XVI

RAILWAY YARDS

OPERATIONS

(1) Fuelling Depots

On all railways, depots are located at stretegic points where diesels may be refuelled and where water and ice for cooling purposes may be taken on board. Diesels are refuelled as fast as possible; with the volume of fuel required, there is invariably some oil spilled during the operation. The spilled oil can saturate the ground adjacent to the fuelling platform and can gain access to the ground-water table. Surface runoff can become contaminated with oil and result in pollution of nearby watercourses. In the more northern areas, spilled oil can be trapped by winter ice and snow and released during the spring thaw in large quantities. Fuelling depots must therefore implement control measures to contain spilled oil and prevent its access to a watercourse.

(2) Roundhouses and Car Shops

Heavier maintenance on the engines and cars is carried out at the roundhouse and car shops. Here, motors, brakes, wheels, etc., are inspected and repaired. Also, cars are washed and cleaned internally and both cars and engines are washed externally.

Roundhouse operations use relatively small amounts of water. Oils are used as a lubricant for heavy machinery or for cutting purposes. Invariably, some oil is lost to sewer. Spent oils are normally collected and shipped in bulk. However, it is impossible to contain all oil spills, so any floor washdown operation will result in oil discharges to sewer. When the engines and cars are washed, soap and detergent cleaners are used. This gives rise to liquid effluents which contain oils in emulsion along with dirt and grit. In some cases, steam generators are used and oily condensate is discharged to sewer.

WASTE CONTROL AND TREATMENT

(1) Fuelling Depots

The main source of oil pollution at the depot results from spills occurring during fuelling operations. Drip collection pads should be constructed on the tracks under the diesel engines to catch and contain spills. Oil collected in the pads should drain to a trap or separator to be recovered.

(2) Roundhouse and Car Shops

Roundhouse waste contain oil and suspended solids. It is normally sufficient to pass the wastes through a large separator to settle out the solids and trap the oil. When detergents are used, the oils become emulsified and cannot readily be removed by simple gravity separation; chemical treatment may be necessary to break these emulsions. To avoid emulsification, some yards use steam for cleaning diesels. This also reduces the volume of wash water used. The condensate from this operation can easily be handled in an oil separator. Good housekeeping practices have also reduced the frequency of oil spills and the amount of oil discharged to the sewer.

A variety of materials containing high concentrations of solid and dissolved matter are washed from the cars on the washing racks. A widely variable waste quality results, which requires sophisticated treatment to produce an acceptable effluent.

Spilled oil is the major problem at railway yards. The installation of suitable oil separation and recovery facilities where necessary is most important.

CHAPTER XVII

SERVICE STATIONS AND GARAGES

In Canada, there are in excess of 30,000 branded retail outlets which dispense gasoline and fuel oil. Of this figure, approximately one-third, or 10,000 outlets, are in the Province of Ontario. In the Province, there are in excess of two and one-half million passenger cars, 400,000 trucks and 13,000 buses. With such a number of vehicles and the resultant number of oil changes and lubrications required, it is essential that the accidental spillage of petroleum products within service stations be kept at a minimum.

Most, if not all, service stations located in municipalities are equipped with standard API interceptors with treated effluents directed to the sanitary sewer system. All floor drains within the confines of the station are directed to the interceptor. The interceptor removes the petroleum product which contaminates the ordinary flows from the station. It is essential that routine maintenance of the interceptor be performed by the service station staff in order to ensure that the interceptor functions as designed. The oils and lubricants that are pumped from the interceptors at specific intervals must be retained in holding tanks until removed by disposal.

Until recently, the service station operator had little trouble in having these tanks pumped periodically by companies that take the spent oil to various locations where it is re-refined or utilized in some other manner. However, due to the tremendous increase in the quantities of used oil, the various liquid haulage companies are now charging the service station operator two to three cents per gallon to dispose of the oil. With this service now being a cost to the service station, the ultimate disposal of the oil is at the discretion of the station owner. For the most part, stations have oil removed by haulage companies.

However, in certain instances, unaccountable and perhaps avoidable accidents resulting in the discharge of oil from a service station to a ditch or nearby watercourse have been reported. Increased surveillance of these stations, therefore, must be maintained by the municipality to ensure that the oil is disposed of in a totally satisfactory manner.

Another source of contamination from service stations is leaking underground gasoline storage tanks. Although all operators are required by law to maintain a record of daily dips of underground storage tanks, these tanks will sometimes spring leaks which can go undetected for a considerable length of time. This may result in some groundwater contamination and, in certain cases, gasoline seeping into basements of adjoining houses. Unfortunately, under present legislation a municipal official can do little to ensure that underground storage tanks are properly maintained to avoid leaks.

As shown in Figure 17-1 of the standard service station interceptor, each chamber has its own manhole and cover to allow for proper cleanout of the unit at a specific time interval. The flow of contaminated waste enters the interceptor from the left. The siphons between the chamber, each six inches from the bottom of the interceptor, allow the oily material to accumulate at the surface and only clear water to overflow to the adjacent compartment. The discharge from the interceptor should be free of ether soluble material. Occasionally, the periodic maintenance program is neglected and a build up of solids reduces the separating capabilities of the unit.

Often a correctly designed separator is found to be connected, unknowingly perhaps, to a storm sewer. This compounds the problems resulting from improper maintenance. It is an accepted practice at many service stations to use acid from trade-in batteries for cleaning grease and oil covered floors. The solution is washed down the drainage system. Depending on the volume of water mixed with the acid, it could affect the operation of the separator or result in damage to the sewers. A special check should be kept on the larger stations and garages to ensure that this practice does not adversely affect the sewer system.

Occasionally, some stations will perform oil changes outside the buildings or stockpile empty oil tins or drums in a location where subsequent rainfall will result in an oily runoff. This runoff could be a serious problem if the station or garage is located on the bank of a watercourse or has storm sewers that drain to the creek.

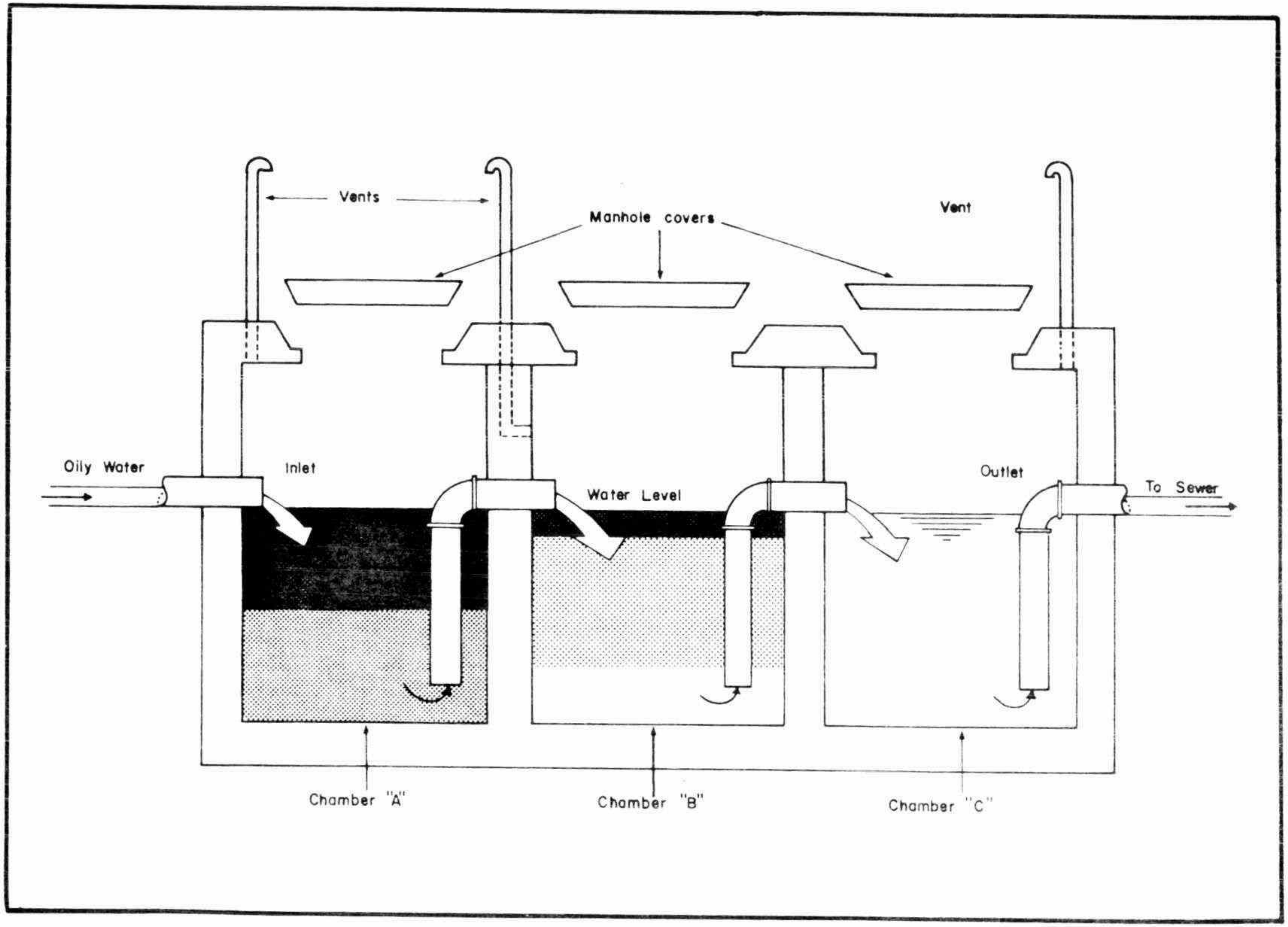


Figure 17-1
Service Station Oil Interceptor

CHAPTER XVIII

CAR WASHES

Waste discharges from car washes are not generally a problem. The BOD is usually under 100 parts per million, pH in the 6-8 range, grease 20-40 parts per million and suspended solids can vary from less than 100 to 600 parts per million. This type of waste presents no problems to the modern sewage treatment plant. Most car washes have at least a three-stage interceptor to provide a partial treatment of the waste flow by removing some suspended material and grease.

There are three different types of car washes:

(1) Coin Operated Do-It-Yourself

This type is a recent innovation. The car is driven into a bay and washed with a high pressure water and detergent solution and then rinsed with clear water. The effluent from the wash bay is discharged to the sanitary sewer with or without benefit of an interceptor, depending on municipal by-laws. These units normally operate on a five-minute cycle with approximately 75-100 gallons of water used per car.

(2) "Roll-Over" Unit

Here the car is parked in the bay and the brushes and applicators move over and around the vehicle. In this facility, an interceptor may or may not be used, again depending on municipal by-laws. Approximately 150 gallons of water are used to wash a car.

(3) "Conveyor" Car Wash

In this unit, the car is driven onto a chain assembly and drawn through a tunnel. The volume of water used per car varies considerably, depending on the amount of time the car spends in the tunnel. On a less busy day, the car moves through the tunnel more slowly, receiving a better wash, with more water. On busier days, cars move faster and receive less water per car. The average water consumption in the conveyor system is 50 gallons per minute. In older installations, all water is discharged to a sump and overflows continuously to the sanitary sewer. Some years ago, reclaiming the water became economical and piping was changed to allow the first flood on the car to be made up of reclaim water. The water is reused in a closed loop system and the only treatment provided is solids removal. It was found that by using reclaim water, which was slightly abrasive and contained some detergent, the car was washed cleaner than when fresh water was used.

A more modern method presently being investigated is that of total reuse. In each portion of the car wash cycle (the first flood, the application, and the final rinse), the water is recirculated within each stage, which is equipped with a gravel filter and a carbon filter to remove suspended solids, wax, and some of the detergent. This unit operates on a total recirculation basis. To keep the dissolved solids concentrations as low as possible, 5-10 gallons of water are discharged at the end of the day's operation. In locations where there are no sanitary sewers, this small flow is directed to a septic tank and field tile system.

One of the problems inherent in the total recirculation system occurs in the winter months. The build-up of chlorides from road salt applications contaminates the recirculated water to such an extent that intolerable spotting of the car occurs. Since no economical method has so far been devised to counteract this problem, it is necessary to have the chloride-saturated solution pumped out at certain intervals and disposed of in an acceptable manner. Liquid waste haulage companies perform this service. Another characteristic of the total recirculation system is periodic backwashing of the filters. The backwash is also removed by a liquid haulage company for disposal. The principle advantage of the total recirculation system is the use of much less water to wash a car compared to the older type of car wash. One can easily see the economic as well as the decreased hydraulic flow benefits from the newer system.

Figure 18-1 shows the three systems described.

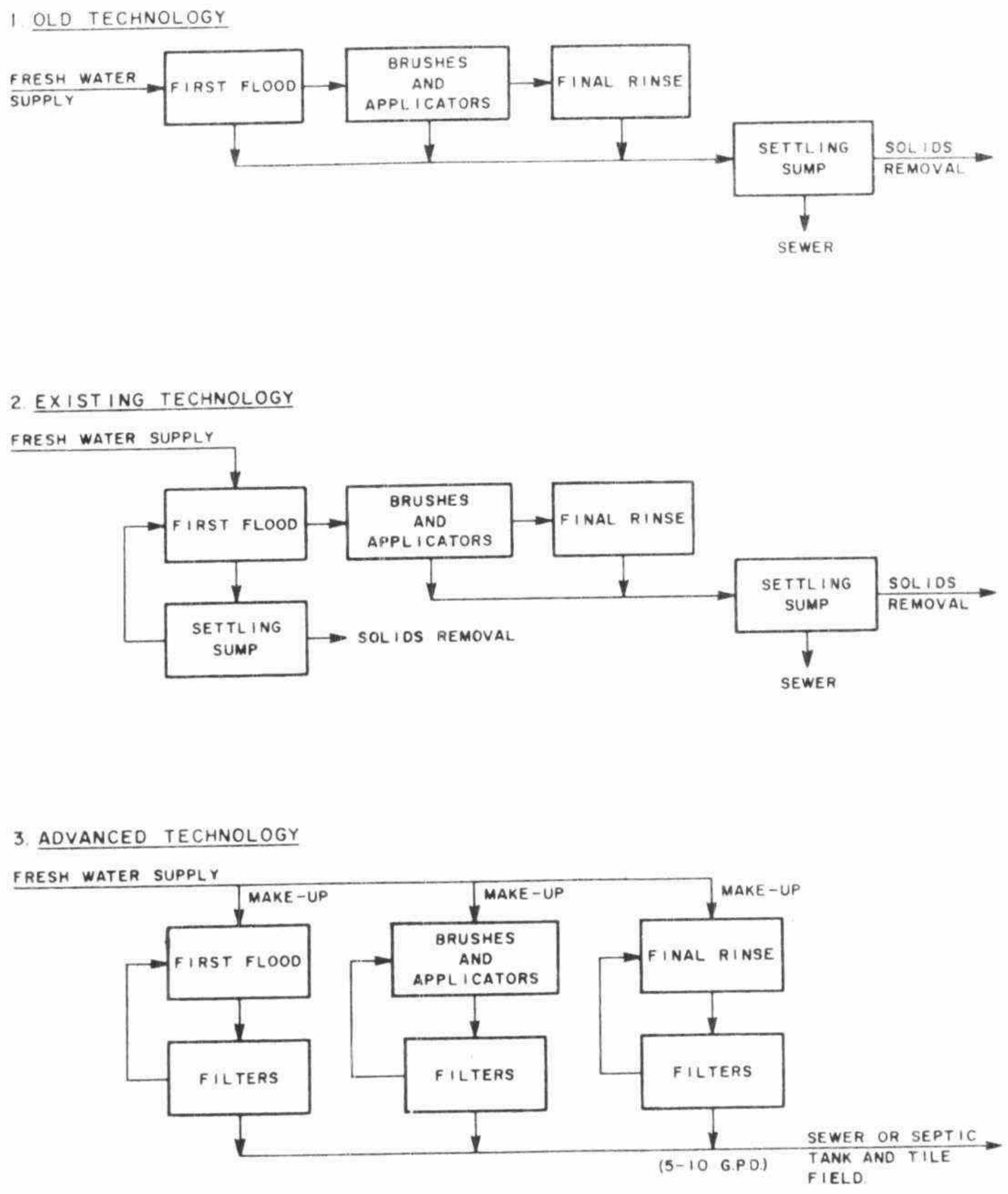


Figure 18-1
Car Wash

CHAPTER XIX

WATER TREATMENT AND CONDITIONING

Water treatment and conditioning operations may be classified as follows:

(1) Boiler feed water treatment
(2) Cooling water treatment
(3) Process feed water treatment
(4) Wastewater treatment

All of these operations require the use of chemicals and all give rise to wastewater discharges containing these chemicals.

Boiler feed waters are chemically treated to:

- prevent corrosion;
- minimize scale build-up; and
- make the best use of the feed water to produce steam.

High pressure systems for power generation usually involve complete demineralization by ion exchange.

Chemical treatments are applied to cooling water systems (most commonly the recirculating type of system) to:

- prevent corrosion;
- minimize scale build-up and deposition of entrained suspended solids; and
- prevent the growth of bacterial and fungal slimes and the consequent attack and decay of cooling tower materials.

Process feed water treatment depends upon the feed water quality requirements. This may range from simple screening to alum flocculation, colour removal, and/or ion exchange demineralization.

Wastewater chemical treatments are commonly associated with specific pollution and/or aesthetic problems. This may involve coagulant aids for suspended solids removal, foam control, odour control, and the control of slime growth.

General Characteristics of Chemicals Used in Water Treatment and Conditioning

Boiler Treatment

Boiler feed water treatment falls into two general categories: external treatment and internal treatment. The nature of the treatment and the types of chemicals employed are as follows:

External Treatments

Treatment	Chemical Employed
(1) Hot Process Softening	Lime, Soda Ash, Coagulant Aids, (Polyelectrolytes)
(2) Cold Process Softening	Alum, Lime, Coagulant Aids
(3) Ion-Exchange	
(a) Softening	Regenerants: NaCl, H_2SO_4, HCl, $NaHSO_2$
(b) Demineralization	Regenerants: HCl, H_2SO_4, NaOH
(c) Dealkalizing	Regenerants: NaOH, H_2SO_4, NaCl, HCl

Internal Treatments

	Treatment	Chemical Employed
(1)	Softening	Na_2CO_3, Na_3PO_4, Na_2HPO_4, NaH_2PO_4, $NaPO_3$, $NaOH$, EDTA, NTA
(2)	Dissolved Oxygen Removal	Na_2SO_3, Hydrazine
(3)	Dispersants or Sludge Conditioners	Na Lignosulfonates, Tannins, Polyacrylates, Polyacrylamides, Acrylonitriles, Na_2SiO_3
(4)	Corrosion Control	Morpholine, Cyclohexylamine Octadecylamine, N.N.-diethylethanolamine.

Other boiler treatment chemicals include clean-out compounds and descalers such as citric acid and sulfamic acid as well as boil-out compounds which are essentially alkaline phosphate solutions with traces of chromate.

Cooling Water Treatment

Cooling water treatments fall into three general categories: corrosion controls, scale inhibitors, and biological growth controls.

Corrosion Control	$NaPO_3$, Na_2HPO_4, $Na_2Cr_2O_7$ Modified Lignins, Tannins, Organo-phosphorus Compounds, Zinc Compounds.
Scale Control	Phosphates and Sequestrants such as EDTA and NTA.
Biological Growth Control	
Chlorine Chemicals	Na or Ca Hypochlorite, Chlorine, Stabilized Chlorine Dioxide.
Chloro-phenols	Na Pentachlorophenate, trichlorophenate, etc.

Organo-sulphur	*Na Dimethyldithio Carbamate* *Mercaptobenzo thiazoles.*
Bromo-Ketones	*2 - Bromo - 4 - Hydroxy Acetopheonone Bis 1.4 Bromoacetoxy - 2 - butene.*
Amines and Quaternery	*Benzyl Ammonium Chloride*
Ammonium Compounds	*Coco amines*
Broad Spectrum	*Na-menthylene-bisisothiocyanate*

Water and Waste Treatment Chemicals

Water and waste treatment chemicals have wide application in industry. Some of these chemicals and applications have already been discussed in the sections dealing with boiler and cooling water treatments.

The following are the categories of uses in the water and waste treatment field and the chemicals associated with these uses:

(1) Flocculants and Coagulants

(i) Alum

(ii) Polyelectrolytes

- *(a) Polyacrylamides*
- *(b) Sulphonated aromatics*
- *(c) Polyacrylimides*
- *(d) Polyglycols*
- *(e) Naturally-derived polymers*

(2) Corrosion Inhibitors

(i) Phosphates (Zinc)

(ii) Chromates (Non-potable water systems)

(3) Chemical Oxidants and Bacteriocides

(i) Chlorine

(ii) Hypochlorite

(iii) Chlorine Dioxide

(iv) Ozone

(4) Sequestrants - Chelating Agents (Non-potable water systems)

(i) E.D.T.A. (Ethylene Diamine Tetraacetic Acid)

(ii) N.T.A. (Nitrilo Triacetic Acid)

(iii) Phosphates

(5) Scale Inhibitors (Non-potable water systems)

(i) E.D.T.A.

(ii) Acids

(iii) Phosphates

(iv) N.T.A.

(6) Defoamers (Waste Treatment Predominantly)

(i) Petroleum Distillates (Kerosene)

(ii) Long Chain Fatty Alcohols

(iii) Paraffin oils

(iv) Silicone hydrocarbons

(v) Esters (Polyglycol esters, ethoxyglycerides, etc.)

(7) Demulsifiers (Waste Treatment Systems)

(i) Inorganic salts (ferric chloride, calcium chloride)

(ii) Acids

(iii) Polyelectrolytes

(8) Ion-Exchange Systems, Regenerants

See under Boiler Water Treatments.

(9) Acids and Alkalies

Usually inorganic. Such as H_2SO_4, $NaOH$, Na_2CO_3

(10) Odour Control Agents

(i) Chloro benzenes

(ii) Perfumed oils

(iii) Esters

Waste Discharges Arising from Water Treatment and Conditioning

All of the water treatment and conditioning processes discussed lead to discharges to a sewer, resulting in a loss of chemicals used in the processes.

Blow-downs from boiler systems using internal treatments may be as high as 10 percent of feed water requirements with less blow-down for the high capacity plants. Typical boiler water conditions are in the following ranges:

Total alkalinity as $CaCO_3$	325 - 500 ppm
Caustic alkalinity	180 - 350 ppm
Phosphate	10 - 40 ppm
Total Dissolved Solids	1,400 - 2,800 ppm
Suspended Solids	Trace - 400 ppm →
Chelates (EDTA, NTA, etc.)	10% to 15% above stoichiometric requirement

The characteristics of wastewater discharges from boiler treatments using external processes such as suspended solids removal, softening and demineralization are less well defined:

> *Suspended solids removal processes* involving alum and polyelectrolyte flocculation produce clarifier sludge discharges containing suspended solids and precipitated iron.
>
> *Softening processes* may produce high chloride backwashes and/or precipitated calcium salts.
>
> *Demineralization processes* involving ion exchange produce highly acidic and highly alkaline waste discharges from the regeneration of ion exchange columns.

Generally, blow-down from boilers using internal treatments present no problems when discharged to municipal sanitary sewers. The discharge of these wastes to storm sewers and surface waters should be discouraged.

Clarifier sludges, demineralizer regenerants and softener backwashes constitute concentrated liquid wastes and should be handled accordingly. Acidic and alkaline rinse waters from demineralizer regeneration can be mixed to provide a degree of neutralization and, under controlled circumstances, can be discharged to storm or sanitary sewers.

Corrosion control is achieved by a corrosion resistant coating on the metal surfaces using chromates, phosphates, zinc salts, tannins and lignins in a variety of formulations. Tannins, lignins and polymeric compounds are also incorporated into corrosion inhibitor formulations as dispersants for suspended matter picked up from the air in open recirculating cooling water systems.

Chromium and zinc are extremely toxic to fish and other aquatic life. Zinc also adversely affects fish reproduction.

Current Ministry of the Environment effluent objectives for these metals in discharge to natural waters are 1 ppm maximum.

Operating concentrations for chromate in open recirculating cooling systems are in the range of 15 to 80 ppm. Operating concentrations for zinc may be 2 to 15 ppm as zinc sulphate in the phosphate/chromate/zinc formulations and 10 to 20 ppm in the zinc/organic formulations.

Operating concentrations for these chemicals in closed recirculating cooling systems may be 10 to 20 times greater than in the open systems. The use of zinc/phosphate and zinc/organic formulations as alternatives to chromates has not been widely accepted by the industry.

Blow-down losses from open recirculating cooling systems are controlled to maintain concentration cycles in the system in the range 4 to 6. This generally produces a blow-down loss of 0.05 to 1.10 percent of circulating water rate. In large scale cooling systems, losses of chemicals can therefore be quite significant. Blow-down losses from closed recirculating systems seldom occur, although systems may be drained for maintenance.

In addition to seeking alternatives to zinc and chromium chemicals, some suppliers offer chemical or ion-exchange waste treatment processes for the control of chromium losses. These are only applicable to large cooling installations at present.

Algae and other biological growths may be controlled by shock chlorination using chlorine or hypochlorite solution, or by adding 40 to 50 ppm of chlorophenate or quaternary ammonium slimicide. Chlorination cannot be used for humidifiers or air washers due to safety and health considerations.

Fungal growths are usually controlled by using a broad spectrum slimicide such as methylene-bis-**isothio**cyanate at dosages of 5 to 10 ppm for short periods.

It is common practice to alternate treatments on a weekly or monthly basis so that blow-down from the system may at any time contain a variety of biocide residues.

Products designed to kill algae and fungi or to inhibit their growth will also be similarly toxic to other higher forms of aquatic life. The precise effects of many of these products on fish and other aquatic life have yet to be determined. Consequently, the discharge of wastes containing these products into natural waters should be discouraged.

Since there are no apparent adverse effects when these products are discharged to municipal sanitary sewers, this seems to be the better alternative.

Use chlorine chemicals and other chemical oxidants as alternatives to organic chemical biocides particularly where wastes are being discharged to surface waters or storm sewers. In spite of their toxicity, these chemicals are relatively unstable and break down quickly into innocuous by-products. In fact, residuals of chemical oxidants in discharges to sanitary sewers would be beneficial because of their capacity to oxidize organic matter.

However, residual chlorine in the presence of ammonia produces quite stable and toxic chloramines. Also, residual chlorine can poison aquatic life.

In general, ion exchange regeneration wastes, corrosion inhibitor losses, flocculant and coagulant losses and scale inhibitor losses have the same characteristics whether they are associated with boiler water conditioning, cooling water treatment or water and waste treatment processes. Certain industrial waste treatment applications of these chemicals and processes may cause waste discharge problems characteristic of the industry. These will be discussed later.

Foam suppression, emulsion breaking, and odour control.

A variety of chemicals are employed as defoamers. Generally, these chemicals are inert, suppressing foam physically. The only defoamer having potentially adverse effects on the aquatic environment is kerosene, and its use in the pulp and paper industry has been curtailed. The significance of the remaining defoamers has not yet been assessed.

Emulsion breaking chemicals (demulsifiers) can cause contamination problems from the chemical residual and the oil released from the emulsion.

Consequently, these chemicals are usually employed as a treatment prior to some other form of physical separation to remove oil and suspended matter. The acceptability of the effluent discharged from such a system for disposal to a storm sewer or surface water often depends on the efficiency of the physical separation.

Of the three classes of odour control agents mentioned previously, the chloro benzenes are of most concern since they kill bacteria and mask odours. They are significantly toxic and should only be used in situations where the discharge receives secondary biological treatment. Excessive quantities of these chemicals, when discharged to municipal sewerage systems, may prove toxic to sewage treatment processes.

Since many areas of specialty chemical usage such as boiler treatment, cooling water treatment, water conditioning and waste treatment are not a major hazard to sewage treatment processes, these wastewaters should be directed to municipal sanitary sewers regulated to eliminate any adverse effects to the sewage treatment processes. The use of other special chemicals constitutes more difficult problems both from lack of knowledge about the effects of certain chemicals and the absence of non-polluting alternative chemicals.

Hopefully, industry will cooperate to deal with these problems to determine the effects of specific chemicals and in the development of less hazardous chemicals.

CHAPTER XX

CHEMICAL MANUFACTURING

This broad classification of industry may be sub-divided into the following categories:

(1) Organic Chemical Synthesis

- (a) Aromatic Solvents
- (b) Basic Raw Materials - Olefins, etc.

(2) Organic Chemical Processing

- (a) Polymers - Rubber, Plastics, PVC, Polyolefins
- (b) Synthetic Textiles
  - Dacron
  - Nylon
  - Acrylics
- (c) Detergents - Alkyl Benzene Sulphonates
- (d) Agricultural Chemicals
  - Fungicides
  - Herbicides
  - Insecticides
- (e) Rubber Chemicals
  - Stabilizers
  - Accelerators
  - Antioxidant
- (f) Chemical Specialties
  - Corrosion Inhibitors
  - Descalers
  - Defoamers
  - Cleaners
  - Slimicides
- (g) Pharmaceuticals

(3) Inorganic Chemical Manufacturing

- (a) Sulphuric Acid
- (b) Caustic Soda and Chlorine
- (c) Soda Ash
- (d) Fertilizers

(4) Packagers and Formulators

Many of these categories are unlikely to discharge process wastes to municipal sewers. However, with proper segregation of process wastes from high volume cooling water discharges, the potential does exist for some of these categories to discharge to municipal sewers. It can be generally assumed that the large chemical plants manufacturing basic chemical raw materials and the large capacity secondary manufacturers do not discharge process wastes to municipal sewers. The small secondary manufacturing plants processing the basic raw materials usually discharge to municipal sewers.

CHARACTERISTICS OF CHEMICAL PLANT WASTES DISCHARGED TO NATURAL WATERCOURSES

(1) Organic Chemicals Synthesis

Organic Chemicals Synthesis includes the broad class of petroleum and petrochemical processors manufacturing and/or extracting the basic organic raw materials for the plastics, polymers, rubber, agricultural chemicals and pharmaceuticals industries, usually from petroleum-based feedstocks. Also included in this category are chemical plants associated with the major steel mills processing coke oven liquors and coal tars.

The wastes from this broad industry group have a high organic content, including dissolved hydrocarbons, floating oils, phenolics, and nitrogen compounds. Such wastes can be toxic to aquatic life, taint the flesh of fish, and adversely affect the taste and odour of public water supplies. Fluctuations in pH and inorganic dissolved solids content can also be anticipated due to acid and alkali extraction and washing processes.

(2) Organic Chemical Processors

Included in Organic Chemical Processors are the major manufacturers of plastics, resins, polymers, synthetic rubbers and agricultural chemicals. Plants in this category are often associated with, or integrated with, plants in Category I and the nature of the waste discharges is difficult to differentiate from that category.

Wastes associated with polymers and synthetic rubber manufacturers tend to be more highly organic, often include particulate organic matter such as latex crumb. The plastics and agricultural chemicals manufacturers may discharge wastes which are more toxic due to the presence of chlorinated hydrocarbons or complex pesticide residues.

Pharmaceutical manufacturers usually discharge wastes to municipal sewers.

Synthetic textiles manufacturing is usually an integrated operation from the preparation of the raw material to the synthesis of the polymer. Spinning of the polymer into the textile fibre is usually a secondary operation carried out elsewhere. Wastes from the polymer manufacture are highly organic, sometimes toxic, high in nitrogen content (from nylon manufacturing) and sometimes high in inorganic dissolved solids.

The manufacture of synthetic detergents is usually divided between the alkyl benzene manufacturers (usually the oil and petrochemical companies) and the detergent manufacturers (the soap companies). In the manufacture of the alkyl benzene, the wastes produced resemble oil refinery wastes, i.e., mostly cooling water with traces of oil and organics. Losses of acid catalyst (either sulphuric acid or hydrofluoric acid) are also possible. The detergent manufacturing operation give rise to alkaline or acidic wastes.

It is difficult to generalize about the characteristics of wastes from the manufacture of rubber chemicals and chemical specialties, but they are often complex mixtures of trace organics which may be toxic to all forms of aquatic life. However, many of the chemical specialties manufacturing processes involve the use of generally innocuous materials so that toxic wastes cannot always be anticipated from this type of industry.

(3) Inorganic Chemical Manufacturing

Sulphuric acid manufacturing usually involves the use of elemental sulphur or waste sulphur dioxide as a raw material. Wastewaters associated with the process are mainly cooling water, which may be contaminated with traces of acid.

Caustic soda and chlorine are manufactured by the electrolysis of brine in either diaphragm or mercury cells. Wastes associated with these processes include brine losses, brine treatment sludges, spent acids and traces of mercury.

Soda ash (sodium carbonate) is usually manufactured from brine by the Solvay process. Wastes associated with this process include calcium chloride, calcium sulphate, high pH and high dissolved solids content.

Fertilizer manufacturing falls into two general categories: phosphate based and nitrogen based. Phosphate based fertilizers are manufactured by acid treatment of phosphate mineral. They may be combined with nitrogenous materials in a variety of formulations. Generally, the wastes associated with this process are high in dissolved and suspended solids, phosphates, and contain traces of fluorides.

Nitrogen fertilizers may be based on ammonia, ammonium nitrate, urea and to a limited degree cyanamide.

The ammonia based fertilizers are usually derived from the synthesis of ammonia from atmospheric nitrogen and hydrogen synthesized from natural gas. Oxidation of ammonia produces nitric acid. The wastes from these processes are cooling waters and condensates containing traces of ammonia and nitrates.

Ammonia and carbon dioxide are reacted under pressure to produce urea. Wastes associated with this process include ammonia liquors and condensates from urea crystallization and drying.

CHEMICAL MANUFACTURING WASTES DISCHARGED TO MUNICIPAL SEWERS

The general characteristics of wastes from the large capacity basic chemical manufacturers and the large capacity secondary processors are similar to the wastes from the smaller secondary manufacturing plants discharging to municipal sewers. The wastes from these smaller plants are generally not as complex as those from correspondingly large scale primary manufacturers, but, collectively, their indirect impact on the aquatic environment via municipal sewerage systems can be just as significant.

(1) Organic Chemical Synthesis

Encountering small scale plants in Organic Chemical Synthesis and the discharge of wastes from such operations is not anticipated. Aromatic solvents are handled in a wide variety of industries and are known to be toxic to aquatic life. They are generally biodegraded in municipal treatment systems provided the levels encountered in the raw sewage do not exceed the tolerance level of the treatment process.

(2) Organic Chemical Processing

The types of plant in this category likely to discharge wastes to municipal sewers include those plants utilizing organic chemical material in some form of secondary manufacturing.

Plants processing rubber, plastics and other polymers are included. These plants generally do not constitute a problem in municipal sewage treatment since the bulk of the water they use is for cooling purposes.

Some plants, however, such as those processing latex, may discharge organic wastes high in suspended solids and acidity or alkalinity. These are the exception.

Synthetic textile secondary processors do not appear to constitute a major problem in municipal sewerage systems, although here the wastes may be high in nutrients, alkalinity, detergents, and be highly coloured from dyeing operations.

Detergent manufacturing is commonly associated with the major soap companies, but there are also many small scale formulators of specialty detergents and cleaners. In general, the wastes from such plants may be highly organic, acidic, or alkaline, and exhibit acute toxicity to fish and other aquatic life. They do not, however, appear to affect sewage treatment processes adversely.

Agricultural chemical manufacturers discharging wastes to municipal sewers are generally small scale packagers and formulators. However, the materials handled, especially the pesticides, can be hazardous to municipal sewerage systems through spills and other accidents. On the other hand, the manufacture, handling, and sale of pesticides are governed by stringent federal and provincial legislation to make spills and accidents unusual occurrences.

Rubber chemical manufacturing is a specialized secondary chemical manufacturing category. The wastes from such plants are highly organic and very toxic. The wastes are amenable to treatment in municipal sewerage systems, but only if the system is modified to handle the wastes.

Chemical specialties manufacturers fall into the category of formulators and packagers. There is a wide diversity of chemical specialties and the nature of the wastes associated with their manufacture is quite variable. The detergent manufacturers, to some degree fall into this category. Apart from the detergent manufacturers, there is little chemical manufacturing associated with the production of chemical specialties. Most of the operations are simply blending raw materials and packaging.

Therefore, potential waste discharges to municipal sewers from such plants result from equipment clean-ups or spills and other accidents. In both cases, the contents of the wastes depend on what is being manufactured. The potential effect on municipal sewerage systems of chemical specialties:

(a) Synthetic detergents and cleaners have been dealt with previously. They are generally biodegradable, although often acutely toxic to aquatic life.

(b) Corrosion inhibitors may contain phosphates, zinc or chromium. There are also organic and silicate formulations, although the phosphate-zinc-chromate formulations are most common. Acute toxicity is the most significant potential hazard from the discharge of these materials.

(c) Descalers are commonly acidic in nature.

(d) Defoamers may be refined hydrocarbons petroleum distillates, or silicone compounds. Generally, they are chemically inert and not readily degraded in municipal treatment systems.

(e) Slimicides are a broad category of toxic organic materials used for the control of fungus and other slime growths in industrial equipment. By their very nature, they are likely to affect sewage treatment processes adversely although certain types are biodegradable.

Pharmaceuticals manufacturing does not generally give rise to large volumes of liquid wastes. The operation demands strict control of losses. No major problems have been encountered in Ontario from the discharge of pharmaceutical manufacturing wastes to municipal sewers.

(3) Inorganic Chemical Manufacturing

Small scale plants discharging wastes to municipal sewers are more common in the inorganic than in the organic chemicals industry. However, there are no small scale caustic soda, chlorine, or soda ash producers in Ontario discharging wastes to municipal sewers. This leaves the small sulphuric acid plants and the fertilizer producers. The small sulphuric acid producers exhibit the same problems as their larger counterparts, namely, high volume cooling waters with traces of acid loss. The small scale fertilizer producers pose a different problem, mainly from the standpoint of inadequate housekeeping and materials handling practices. Generally, these plants are essentially dry operations and water pollution problems arise from surface runoff contaminated by spilled raw materials and product. This may constitute a nutrient problem in the receiving waters.

A further category of small scale inorganic chemical manufacturing, unique to municipal water pollution control, is the production of industrial gases such as acetylene, oxygen, carbon dioxide, etc.

Of most concern is the manufacture of acetylene from calcium carbide and water. This gives rise to large quantities of calcium hydroxide sludge and a highly alkaline liquid waste. The sludge constitutes a significant solids waste disposal problem. The liquid effluent can be discharged to municipal sewers, provided it is reasonably free of suspended solids. This is not always the case.

(4) Packagers and Formulators

Plants in this category have been covered in detail under Chemical Specialties Manufacturers. However, the potential problems from their discharges centre around the nature of the materials being formulated or packaged and the housekeeping and materials handling practices of the individual plant.

The general characteristics of waste discharges from the four major categories of chemical industry are summarized in Table A.

TABLE A

GENERAL CHARACTERISTICS OF WASTE DISCHARGES - CHEMICAL INDUSTRY

CLASSIFICATION	*VOLUME*	*CHARACTERISTICS*
Organic Chemical Synthesis (1)	*High volume cooling waters. Low volume contaminated wastes.*	*High dissolved organic content. Some toxic and taste and odour producing contaminants. Floating oils and inorganic acids and alkalies.*
Organic Chemical Processors (2)	*High volume cooling waters. Low volume contaminated wastes.*	*Similar to (1). Polymers manufacturing may produce organic particulates, high nitrogen wastes and non-degradable organics. More potential for inorganic losses than (1).*
Inorganic Chemical Processors (3)	*High volume cooling waters. High volume contaminated wastes.*	*Acid or alkaline wastes from alkali producers. High suspended solids and dissolved inorganics from soda ash plants, gas producers and chlor-alkali plants.*

TABLE A (Continued)

GENERAL CHARACTERISTICS OF WASTE DISCHARGES - CHEMICAL INDUSTRY

CLASSIFICATION	VOLUME	CHARACTERISTICS
Packagers and Formulators (4)	Low waste volume.	Waste characteristics related to materials being processed. Losses may be associated with spills and poor materials handling practices. Toxicity of discharge usually of most concern.

CHAPTER XXI

PULP AND PAPER

Introduction

In general, the surveillance and pollution control enforcement work for the pulp and paper industry in Canada remains the responsibility of the respective provincial pollution control agency or the federal government. Certain pulp and paper making operations, located in larger municipalities can, however, discharge process wastes into the municipal sewerage systems and provide easy solutions to potential pollution problems. In Ontario, there are thirteen such operations located in Metropolitan Toronto, Georgetown, Brantford, Brampton and North Bay. Monitoring and surveillance of the process wastes from these plants is left to the municipality. The Province only becomes involved upon request.

The pulp and paper making operations discharging wastes to municipal sewerage systems are small in size and do not generally include chemical pulping operations. The finished products include a whole range of fine and coated papers, tissues and paperboards. Raw materials used to make these products include purchased pulps, waste paper for recycling, raw paper and raw paperboard. Waste loadings from the mill often represent more than 80 percent of the total loading on the sewer system, so the municipality is actually inheriting the industrial waste problem. There are, however, capital and operating cost benefits for the municipality to offset this.

To enforce sewer-use by-laws or when negotiating the inclusion of a paper mill's wastes in a municipal sewerage system, it is necessary to have some knowledge of the sources and characteristics of the waste streams associated with the various processes.

The manufacturing operations of paper or board are broken into four processing areas that give rise to liquid wastes:

(1) Chemical preparation
(2) Stock preparation
(3) Sheet forming and drying
(4) Coating

In addition, there are converting operations that include coating, embossing, impregnating, saturating, and forming of special shapes and sizes. All can cause liquid wastes. Only coating will be discussed.

(1) Chemical Preparation

Chemical preparation areas exist in all mills and can be sources of heavy waste loadings. The types of chemicals used include fillers for paper, alum for pH control, sizes, resins, glues, starches, dyes, pigments, various acids and alkalis and certain organic chemicals, such as formaldehyde, which are used as solvents and polymerization agents.

The chemicals used in paper making operations are normally received in drums or bags and are made into stock solutions on a batch basis. Some chemicals (e.g., caustic soda and liquid alum) are received in bulk and used directly from storage.

Preparation of stock solutions is most often accomplished in batch mixers which may range from 200 to 1,000 gallon capacity. These solutions may be used directly from the mixer or may be pumped to intermediate storage tanks.

Wastes from the chemical preparation area are normally small in quantity because of chemical costs. It is not uncommon, however, to encounter leakages and spills which find their way into the sewer system, but the bulk of the liquid wastes in this area originates from washing-up of equipment. During the course of a day, the batch mixing equipment may be used to prepare a variety of different chemical solutions, dyes, filler solutions, etc., and wash-ups are required between changes. Occasionally, some surplus stock solution may be dumped causing a sudden surge of wastes to the sewer.

Because of the variety of materials used, it is not possible to indicate any general waste characteristics associated with the chemical preparation area. Suspended solids, pH, and colour are the most common parameters to test for. Biochemical Oxygen Demand (BOD_5) could be significant from certain types of chemicals.

(2) Stock Preparation

The stock preparation consists of the area where the pulp or fibre is prepared before being formed into a sheet on the paper machine. A variety of operations may be encountered in the stock preparation area, depending on the source and type of fibre being used.

If virgin chemical or groundwood pulps are used, the processes are relatively simple. The pulps are slurried by severe agitation in a suitable vessel, undergo some conditioning (beating), are cleaned by screens or centrifugal cleaners, and then sent to storage either as high density or low density pulps. Finally, the pulp slurry is diluted to the consistency required for the paper making operations.

Where recycled fibres are used, the process is more complex and may include some or all of the following stages:

(a) Pulping or defibreing
(b) Cleaning and screening
(c) Washing to remove contaminants
(d) Dewatering or thickening
(e) Bleaching
(f) Bleach washing followed by thickening

Step (c), washing to remove contaminants, may involve de-inking if printed materials form part of the raw fibre supply.

The waste volumes and flows associated with the stock preparation process will vary from mill to mill. There will be the normal process wastes which will vary consierably (as shown in Table A) and there will be wastes generated as a result of spills and equipment wash-ups.

TABLE A

CHARACTERISTICS OF WASTES FROM STOCK PREPARATION AREA

Flow gals./ton of product	Suspended Solids lbs./ton of product	BOD_5 lbs./ton of product
5,000 - 30,000	50 - 600	20 - 150

(3) *Paper Making Operations - Sheet Forming and Drying*

Two types of equipment are used today to convert a dilute suspension of fibres into a sheet of paper or board: the cylinder machine and the Fourdrinier.

In the cylinder machine (Figure 21-1), a wire-covered cylinder is mounted in a vat where the fibre slurry is introduced. As the cylinder is revolved, water drains inwardly through the screen and the sheet is formed on the outside. The wet sheet is is removed at the top of the cylinder, passed through press rolls, and then sent to steam-heated, cylindrical drying drums where the final paper sheet is produced.

In the Fourdrinier (Figure 21-2), fibre slurry is introduced at one end of a continuously moving, horizontal wire screen by means of a head-box. As the slurry moves along with the wire, progressively it loses water. This process is enhanced by special devices placed under the wire, and the wet sheet is formed. The wet sheet then passes through press rolls and dryers as in the case of the cylinder machine.

For both cylinder and Fourdrinier machines, the water that drains from the fibre slurry is known as white-water or machine white-water. This is often a misnomer as "white-water" can be almost any colour.

Where practical, white-water is re-used in the stock preparation areas. Excess white-water is discharged to sewer and represents a major waste source. The felts and wires of these machines must be continuously cleaned by high pressure sprays using fresh water. This shower water is normally sewered and can contain high levels of suspended solids.

White-waters contain large amounts of suspended solids, both fibre and inorganic filler. They can exert substantial BOD_5's if large amounts of organic additives (starch, resin, etc.) are added and may be highly coloured due to dyestuffs. Table B presents some characteristic data for white-waters:

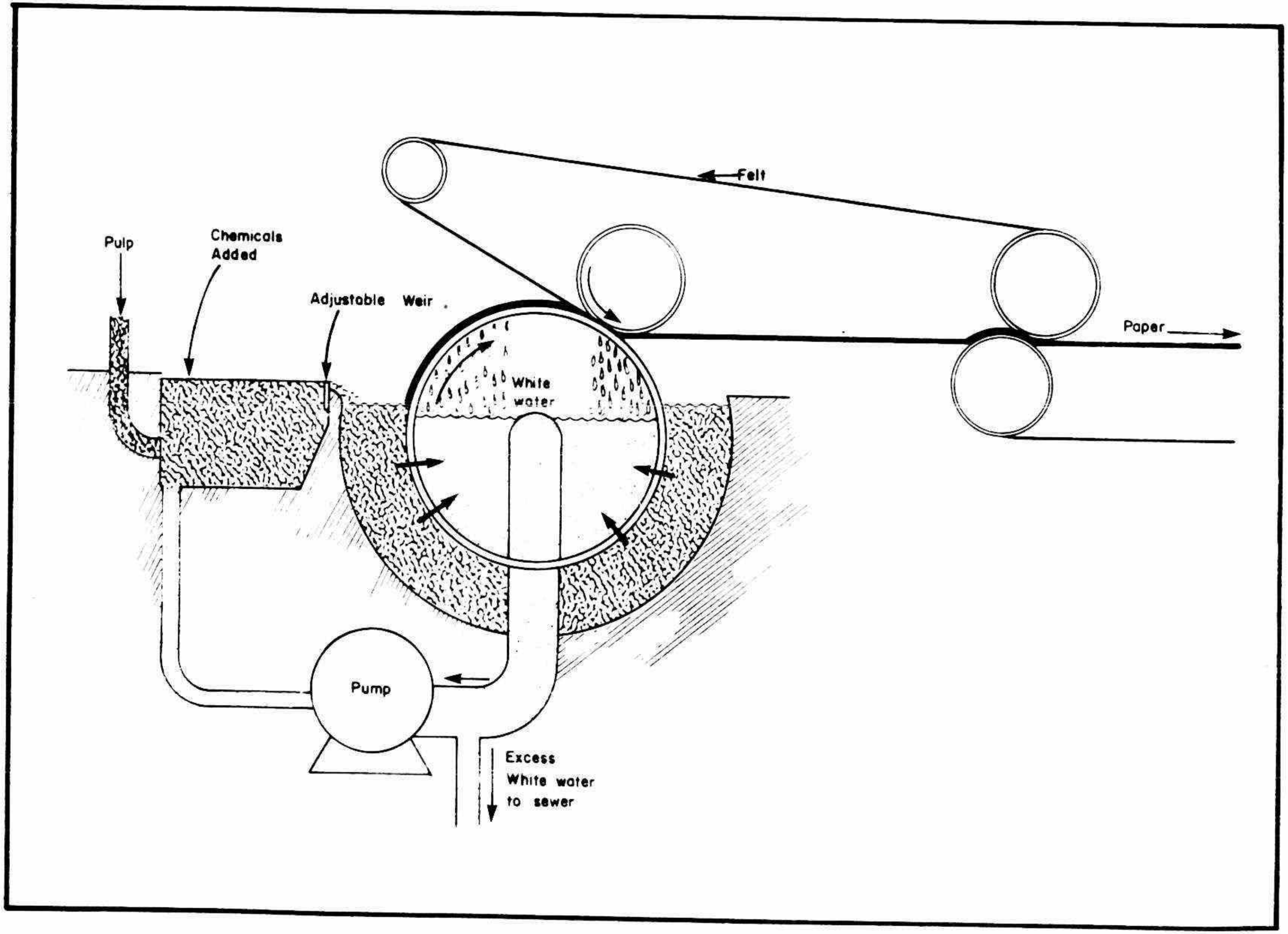


Figure 21-1
The Cylinder Machine

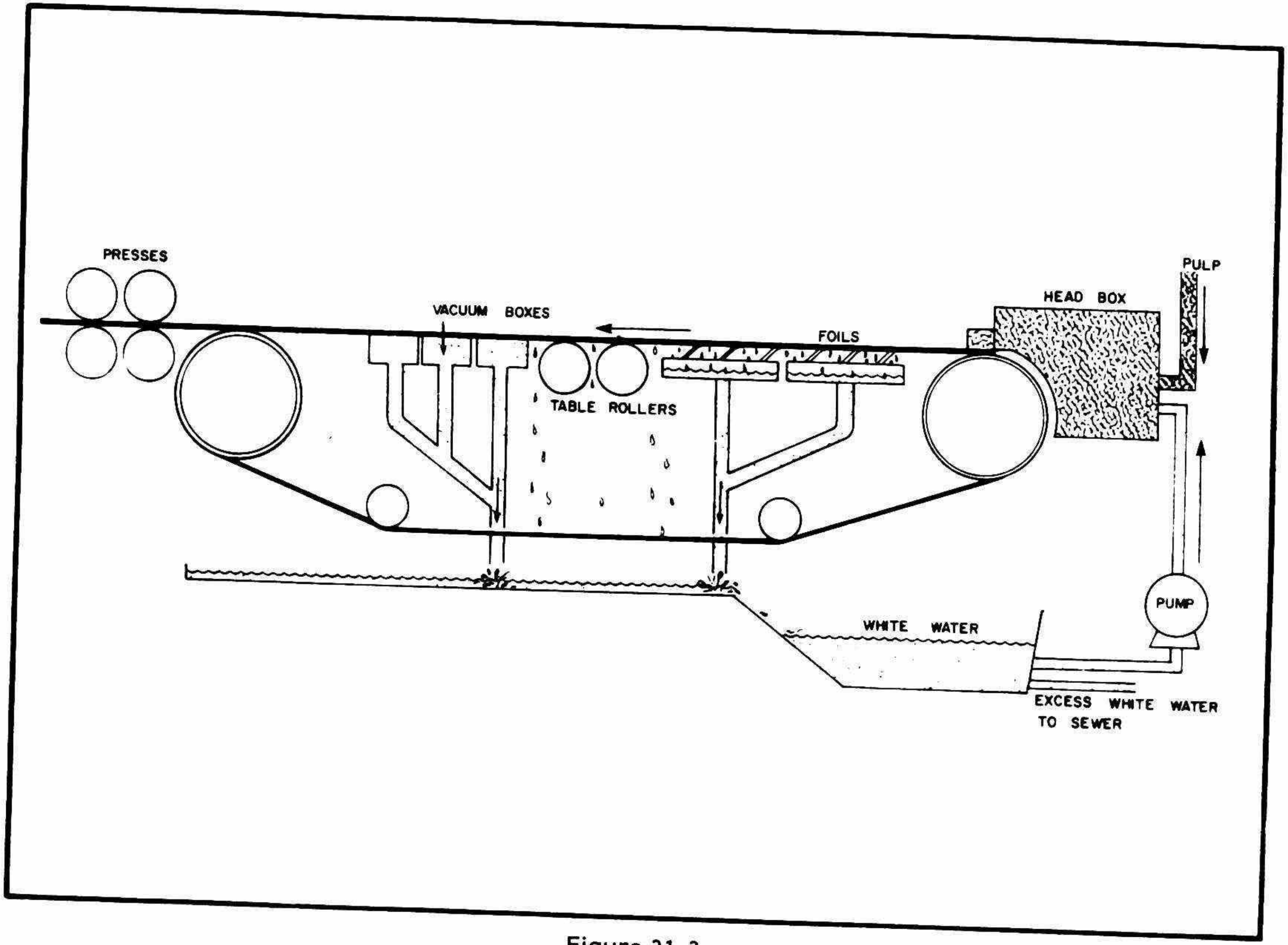


Figure 21-2
The Fourdrinier

TABLE B

CHARACTERISTIC DATA FOR MACHINE WHITE-WATERS

Flow gals./ton of product	Suspended Solids lbs./ton of paper	BOD_5 lbs./ton of paper
2,000 - 60,000	5 - 400	3 - 100

Concentrations of suspended solids are in the range of 300-6,000 mg/l. The lower values originate from the manufacture of simple, unfilled papers and boards and the higher values pertain to bond and book paper manufacture.

Other sources of wastes in this area will include leakage and spillage, head-box dumps and washing-up wastes. In mills which make a number of different grades of product, or mills on 5 or 6-day operation, waste loading from wash-up can be high.

Broke is the name given to scrap paper or board that results from a break on the machine. In most mills, this material is re-used; in some cases, it cannot be re-used due to lack of adequate facilities. Disposal of the material is either in the dry state by hauling to a nearby dump or incinerator, or in the liquid state by slurrying up the broke and discharging the resultant slurry to sewer. This practice is not too common, but can produce a substantial waste loading.

(4) Coating

Coating operations involve applying a mixture of pigments, adhesives, and other additives to one or both sides of a roll of paper. Coatings are applied to mask or change the appearance of the base stock, improve capacity, impart a smooth and receptive surface for printing, and to provide special properties for particular purposes.

Coatings can be applied either on-line to the papers coming out of the dryer section or, more commonly, in a separate, independent operation. Some mills conduct coating operations only, receiving the base paper in large rolls from paper mills.

The coatings are applied to the base paper in the form of a water suspension or coating colour. The total solids content (pigment plus adhesive, etc.) will vary from 35-70%. The coating colour is applied to the paper, usually by roll, with excess material being scraped off by a trailing blade, or blown off by an air doctor. The excess material is collected and recycled so that there are no direct wastes from the application areas other than leakage, etc. Where a coating operation is independent of a paper making operation, it will have its own chemical preparation area generating wastes similar to those already discussed.

The main source of wastes from the coating operations is washing-up. Each time a different grade of coated paper is made, it is necessary to wash down the coating applicator equipment. In some cases, this is done on a daily basis to prevent build-up on equipment.

The frequency of wash-ups, their duration, and the characteristics of the wastes generated should be determined if the wastes are to be discharged to a municipal sewerage system.

Requirements for Discharge to Municipal Sewerage System

The following three waste parameters are important if waste discharge to a municipal sewerage system is being considered:

(1) colour;
(2) suspended solids; and
(3) BOD_5.

The acceptability of the wastes into the sewerage system will depend on adequate sewage treatment facilities associated with the system and the limits imposed on any discharges by sewer use by-laws.

Where secondary treatment facilities exist, colour does not usually present a problem because most dyes oxidize readily. However, a highly coloured effluent from a municipal sewage treatment plant could lead to public criticism of the municipality. The types of dyestuffs being used should be checked to determine whether they are 'refractory' to biological oxidation or not.

Most mill wastewaters will exceed the prescribed limits on suspended solids for discharge to the sewers, making some kind of pretreatment necessary. In certain cases, agreements can be reached wherein the municipality accepts a suspended solids loading in excess of that prescribed by by-law if a sewer use surcharge is paid. Waste volumes, however, may be excessive and may require reduction before being accepted by the municipality.

BOD_5 is rarely a problem in the cases considered here, except for mills operating a de-inking process. At the present time, there is only one such mill in Canada. More may come into existence with the public demand for more recycling of waste paper.

Waste Volume Minimization

Most paper making operations employ maximum re-use of machine white-waters to effect savings on water, heat and to minimize the losses of chemicals and fibre. However, operations are still encountered where the water usage, and hence the waste discharges, are far greater than necessary. In such cases, the companies should be urged to implement a major water conservation program.

Better planning of product grade manufacturing can result in much reduced waste loadings. For example, if coloured grades of paper are being made, it is often possible to schedule the lighter colours ahead of the darker colours and thereby allow excess stock and white-water to be used in the manufacture of the next grade.

One very common source of wastewaters in mills is fresh water hoses left running continuously. This is usually done to have fresh water on hand at all times. Or, a faulty shut off valve may not have been replaced. Self-closing nozzles are available to solve such problems.

An inspection of the processing facilities will quickly reveal areas where excess water is being used. The company official accompanying you during the inspection can tell if a particular water stream is necessary and if it can be reduced or eliminated. Inspectors can often point out to mill personnel that excessive, unnecessary water is being used.

Pretreatment of Mill Wastewaters

Even where water conservation programs are in effect, wastewaters from most paper making operations may not comply with sewer use by-law requirements, particularly for suspended solids. In some cases, special concessions might be made so that the wastes can be treated in the municipal sewerage system upon payment of a surcharge. Pulp and paper companies will ask if it is more economical to pay the surcharge (which will be a continuing payment with no tax concessions) or if pretreatment facilities should be installed where depreciation and other tax concessions might apply.

In other cases, the pulp and paper mills will not have the choice. Pretreatment will be necessary to reduce waste loadings to acceptable levels.

Method Used for Treating Pulp and Paper Wastewaters

(1) Suspended Solids Removal or Reduction

A number of processes are in common use throughout the paper making industry to reduce suspended solids in mill wastewaters, with some being more highly favoured than others. In mill jargon, the equipment installed to perform this task is known as a saveall.

(a) Screening

The use of screens to separate fibrous materials from water is well established in the industry. However, screening is not normally reliable to remove very fine particles because of high operating and maintenance costs. Very fine screens are highly susceptible to plugging and require almost continual back-washing or changing.

A variety of screens are in use, ranging from the simple gravity sidehill screen, through the vibrating and rotary screens to the newer parabolic "D.S.M." type of screen.

(b) Flotation

Dissolved air flotation is a very efficient method used to recover fibre from wastewaters. The process requires constant feed conditions for good performance and tends to be highly susceptible to upsets. Units such as the "Sveen Pederson" and the "Krofta" flotation savealls are quite common to the industry.

Resin polymers having the ability to readily 'float' suspended materials are now available. The cost of these materials is decreasing and their high efficiency, if used with a dissolved air flotation unit, is making them an economically attractive alternative for the industry.

(c) Filtration

Both gravity and vacuum filtration processes are commonly employed to reduce suspended solids. In most cases, the filter units are simple, sometimes using pulp fibre as a 'sweetening stock' to form a filter mat. Where large amounts of very fine particles have to be removed, it may be necessary to use precoat filters. These units are not too common because of high operating costs and the resulting sludge disposal problems.

Vacuum disc filters, vacuum rotary filters, and the simple gravity rotary filters are most commonly used.

(d) Sedimentation

Gravity clarifiers remove suspended solids from liquid wastes. Most are found in external waste treatment facilities. Clarification could also be used as a pretreatment system. Dewatering and disposal of accumulated solids sludges must be considered before installing a clarifier; however, cost will probably be the most important factor to consider.

Sedimentation lagoons or settling ponds are a useful alternative if land is available. One disadvantage is the cost of dredging or cleaning out the accumulations. This is necessary to maintain good efficiency of solids removal. Also, settling ponds will generate odours during warm weather. These odours can be particularly obnoxious and are due to excessive anaerobic biological activity. For this reason, the use of ponds in a built-up area should be discouraged.

Selection of the process to reduce suspended solids will depend on:

(1) the degree of removal required;

(2) the capital and operating costs;

(3) sludge disposal or other related problems;

(4) the general economics of pretreatment versus surcharge; and

(5) aesthetic problems such as odour.

(2) BOD_5

Where pretreatment to reduce BOD_5 is required, any of the conventional biological oxidation systems or chemical treatment methods can be employed. Pretreatment for BOD_5 reduction is rare but it could increase if more waste paper recycling plants are built.

(3) Colour

A colour problem is unlikely if secondary treatment is employed in the municipal sewerage system. In the case of the small town and large paper mill jointly treating wastes without secondary treatment, colour could persist through the system and create an unacceptable aesthetic pollution problem.

Most colours originating from dyes can be broken down by oxidation (chlorination) but certain persistent dyes may require specialized chemical treatment before they can be eliminated. If the colour is associated with a pigment in the colloidal or semi-colloidal state, chemical conditioning may be necessary before the offending materials can be settled out or filtered from the effluent.

(4) Other Waste Parameters

There may be other components in the waste effluents from a paper mill that could be detrimental to the operation of the municipal sewerage system:

(1) An awareness of the operations being carried on in the mill, together with a detailed list of all chemicals used in the processing, should provide ample clues as to whether other conditions might create problems.

(2) Heavy metal ions, present in large enough quantities, could be toxic to the bacteria in a biological treatment system.

(3) Excesses of pH (very high or very low) could create problems in the sedimentation processes and the biological treatment units.

(4) Excesses of phenolic-type materials could pass through a municipal treatment plant without much reduction and cause subsequent water quality problems in the receiving watercourse.

The municipal official needs a good working knowledge of the mill processing and chemical usage, as well as the related problems that can arise and their source, to make responsible decisions on the acceptability of mill wastes for discharge into the sewerage system. Arbitrary decisions without the backing of a thorough investigation could lead to overwhelming problems in the future, or prevent the mill from adopting a solution beneficial to both mill and municipality.

CHAPTER XXII

CONTINGENCY PLANNING

Contingency planning means having a plan of action which can be put into effect immediately when a spill occurs. If such a plan has been prepared and is put into effect immediately, then the adverse effects of spills may be minimized.

Why are contingency plans necessary? If a contingency plan exists, action can be taken to prevent the effects of the spill from spreading and allows prompt action to clean it up. Without a contingency plan, even if a spilled material is eventually cleaned up, it is much more likely to have widespread effects and the consequences of the spill are much more likely to be serious. Today, The Ontario Water Resources Act and The Environmental Protection Act require that a person who spills a material must notify the Ministry of the Environment. Therefore, the actions which were or were not taken as the result of the spill or the means and measures which were used to clean up the spill must be accounted for. Also, it is unlikely that spills will ever be completely eliminated; obviously a contingency plan will assist greatly in handling those spills which do occur.

What types of spills are there? They can be classified as minor spills, moderate spills or major spills. Minor spills can be handled by a municipal or a company contingency plan. Moderate spills require the resources of a cooperative or area contingency plan and major spills would require resources beyond the capability of a local plan; that is, the Provincial Contingency Plan might have to be implemented. Beyond the Provincial Contingency Plan there are Federal Contingency Plans and even International Contingency Plans, but you need not be concerned with these. Your concern is with the development of local contingency measures.

How can a municipal or local contingency plan be developed? First, you must determine the kinds of spills that are likely to occur and where they can be expected to happen. Therefore, a survey of all installations within the municipality, where materials are stored in significant quantities, must be carried out. As a first step you can confine your consideration of materials to those which are liquid. These are much more likely to escape than solid materials, and may spread over the ground or under the ground or via the sewer systems. So liquid storage should be your main concern.

In surveying a liquid storage facility, note the types and quantities of materials stored, the types and condition of the storage containers and observe the operating procedures. Additionally, determine the presence or absence of retaining walls or drainage sumps, etc., and locate the points of discharge of drains and sewers.

The names and telephone numbers of responsible officials in each company must be noted so that they may be contacted at any time during the day or night in the event of an emergency. Any material or equipment which the company may have on hand to cope with a spill should also be recorded. All of this information should be listed and each installation should be given a code number to be placed on a map showing the sewer layout of the municipality.

Secondly, it should be decided whether the plan will be implemented by the municipality alone or by a cooperative consisting of municipal representatives and representatives from industry within the municipality.

Thirdly, vehicles, equipment and supplies to be used if a spill occurs must be obtained and kept at an appropriate place. An emergency team must be formed of persons completely familiar with the procedures required to minimize the adverse effects of spills. These procedures should include the use of barriers, booms, absorbents, oil removal methods, chemical treatment and final clean-up. Plans must be made in advance for the disposal of material recovered from a spill site, and if additional aid is required at a spill, the team should know the appropriate person to contact. A telephone number should be available twenty-four hours per day for reporting spills. The person manning this telephone should have a list of team members, their addresses and telephone numbers, and should be able to contact them to activate the contingency plan.

You may have noticed that the contingency plan is very like the plan which the Fire Department has in effect to deal with fires within a municipality, and certainly the close cooperation and assistance of the Fire and Police Departments should be obtained. When the basic contingency plan has been prepared and you are satisfied with its operation, you may wish to survey industrial and commercial establishments to look for smaller in-plant sources of possible spills.

The operation of road tank vehicles presents another potential spill source. An inventory of possible spill sources may be built up and coded and the locations placed on a map showing the sewer layout of the municipality. In this way, upon notification of a spill the operations team will be able to determine very quickly the possible routes which the spilled material may take from the site of the spill and the final point to which the spilled material will flow, as well as the best means for preventing the spread of the spilled material.

While a contingency plan is a necessity, many spills need not occur and much of your effort should be directed towards their prevention.

The following is a list of procedures to be followed in setting up and maintaining a municipal contingency plan:

(1) Find out what kinds of spills are possible.

(2) Find out where these spills may occur.

(3) Prepare a list of these sites giving location, types of materials and quantities of materials stored.

(4) Give each site a code number and mark its location on a map of the municipality. This map must show storm sewers, sanitary sewers, creeks, ditches and rivers, etc. Indicate the direction of flow.

(5) Prepare a list of the names and telephone numbers (including home numbers) of responsible officials for each site shown on the map.

(6) Prepare a list of names and telephone numbers (including home numbers) of persons

to contact in:

(a) *Works Department, Engineering Department or Public Utilities Commission*

(b) *Police Department*

(c) *Fire Department*

(d) *Health Department*

(e) *Water Treatment Plant*

(f) *Sewage Treatment Plant*

(g) *Ministry of the Environment*

(h) *Industry Cooperatives*

(7) *Prepare a list of specialized and general equipment and services which are available in the area and which may be required if a spill occurs. This list should include such items as oil control booms, absorbents, oil skimmers, sand, straw, pumps, vacuum trucks, waste disposal sites, front-end loaders, emergency portable lighting and power generators, supplies of chemicals of various kinds. The list should also contain the telephone numbers of the owners of such equipment.*

(8) *Decide who is to operate the Contingency Plan and select the members of the Response Team.*

(9) *Arrange for the members of the Team to be thoroughly trained.*

(10) *Carry out practice drills at intervals.*

(11) *Maintain at least a basic inventory of vehicles and equipment which the Team will use in responding to a spill report. This equipment should include absorbent materials (straw, sand, peat moss, polyurethane foam, etc.), a length of floating boom sufficient*

to contain oil in the largest watercourse in the municipality, a skimmer (or skimmer head to be used with existing pumps) to remove floating oil, and limited stocks of selected chemicals for use in certain cases. A portable foam generator would be a useful addition to the equipment list, for use where highly inflammable material such as gasoline is spilled.

(12) Set up an operations centre and publicize its telephone number and the fact that it will be answered twenty-four hours per day.

(13) Set up a basic response plan which will be used upon notification of a spill. This plan should include investigation to determine the nature and magnitude of a spill, alerting and coordinating the resources necessary to deal with the spill and establishing liability for the spill and for the costs involved in dealing with it.

With the above, you will have a workable Contingency Plan, but remember that prevention is better than cure. Therefore, visit each site where a spill is possible and work with management on a program of safety measures to prevent spills.

Additionally, remember that quick action is necessary since a minor spill can become a major incident if left unattended. Do not wait to find out who will pay for clean-up measures. Do the job and send the bill to the responsible person later.

In this brief outline, it has not been possible to deal in detail with every aspect of Contingency Planning. However, the Ministry of the Environment will assist and advise you in setting up your plan. Please do not hesitate to ask.

CHAPTER XXIII

THE MUNICIPAL INDUSTRIAL WASTES CONTROL PROGRAM

I. What is a Control Program?

An industrial wastes control program is a program to control the discharge of industrial (including commercial) wastes to the municipal sewer system.

The following are necessary for successful control:

(a) The determination of the citizens (through the Council of the Municipality) to have control of the inputs to the sewage system.

(b) Enactment of a suitable sewer-use by-law such as that recommended by the Ministry of the Environment.

(c) Development of fair and reasonable charges for industrial sewer service.

(d) Formation of an industrial wastes control service within the municipal organization. In a small municipality, this service might consist of the sewage treatment plant operator working part-time; in a large municipality there may be a full engineering staff handling industrial wastes control.

(e) Full and willing support of the industrial wastes control service by Council, financially, technically and politically.

(f) Comprehensive, confident, common-sense enforcement of the by-law by the industrial wastes control service.

(g) Continual up-to-date knowledge of the status of all industrial discharges to the sewer system by the industrial wastes control service.

(h) Establishment of a Contingency Plan to handle emergency situations.

All of these form an industrial wastes control program. All are essential to the program. If any are missing, the success of the program may be jeopardized.

II. Why is a Control Program Needed?

Municipal sewage systems exist for the purpose of carrying away, treating and disposing of sewage (including certain industrial wastes) to maintain a healthy environment. Any interruption of the service provided by the sewage system, or any drop in its efficiency, or any damage to its structures and mechanisms may lead to damage to the environment.

Also, if a certain type of sewage cannot be treated to the proper degree, direct damage to the environment may result. Remember that there is a solid waste from a sewage treatment plant as well as a liquid effluent. Any substance in sewage which is not broken down in the treatment plant must be present either in the liquid effluent or in the solid waste. The solid waste is discharged into the environment just as is the liquid effluent.

To avoid damage to the environment, or to the sewage system, or to persons, animals and property, the quantity and characteristics of sewage must be controlled.

Sewage systems cost a great deal of money to construct and operate. Most of the costs of the sewers and of the treatment plant are due to the hydraulic load. Most of the operating cost of the primary section of a plant is due to removal of suspended solids. Most of the operating cost of the secondary section can be assigned to removal of BOD. All these costs are different and they must be shared amongst the users in a manner which is fair. Only a certain amount of capacity is available in the sewage system at any time and this capacity must be shared amongst the users in a fair manner. To ensure this, the characteristics and quantity of sewage being discharged by each user must be known and controlled.

The characteristics and quantity of sewage from domestic residences is not considered; only the control of sewage from industrial and commercial sources is required. In summary, an industrial wastes control program is required to ensure:

(a) Protection of persons, animals, property, the sewage system and the environment.

(b) Fair sharing of the costs and available capacity of the sewage system.

III. What are the Roles of Those Involved in a Control Program?

(a) Role of the Government of Ontario

The Government of Ontario is involved in an industrial wastes control program for several reasons.

Firstly, the Government of Ontario is involved because the Municipal Act is a provincial statute. This Act enables a municipality to pass by-laws to regulate the use of sewers and to assess charges for sewer service. The Municipal Act also enables a municipality to make by-laws with respect to many other aspects of drainage and sanitation, making it important to a municipal control program. Only the Government of Ontario can change this Act, so its role in this respect can be clearly seen.

Secondly, a number of acts such as the Local Improvement Act, the Drainage Act and various Provincial Health Acts and Regulations, all have some bearing upon drainage, sewers and use of sewers. Again, it can be seen that the Government of Ontario has a role to play in a municipal control program.

Thirdly, the Ministry of the Environment plays perhaps the most active role, since it has the responsibility to control pollution. If a municipality does not have a good control program, pollution of the water or soil and damage *to sewers and sewage treatment plants often results. A number of sewage treatment plants are operated by the Ministry, so the Ministry has a very direct and active role to play in some municipal control programs. However, the Ministry does not exist just to enforce the terms of the anti-pollution Acts. It also exists to provide services to municipalities, such as water supply and sewage treatment. Important, too, is the technical assistance offered by the Ministry. "Model" by-laws, advice on contingency planning, on industrial problems, on pollution and appraisal of plans, all form part of the Ministry's functions. By offering courses of instruction for municipal employees, the Ministry is attempting to provide municipalities with the expertise necessary to operate a successful waste control program, thereby assisting the work of the Ministry.*

In summary, the Government of Ontario plays a role in a municipal waste control program through provincial statutes and through direct control, advice and technical assistance.

(b) Role of Municipal Council

The Council of the municipality has a fundamental role in the development of a waste control program and must be enthusiastic and serious about having such a program work effectively. It must accept the need for a control program, for passage of a sewer-use by-law and for strong support of enforcement of the by-law.

In establishing a control program, Council must become familiar with the needs of the municipality. Information such as the number and locations of industries, existing or potential problems and benefits to the municipality which the control program will offer (increased sewer life, increased revenue, increased capacity at the treatment plant, better sewage treatment, etc.) is required. This information can be obtained from a report prepared by the "Technical Head" of the municipality, or by consulting engineers if there is no Technical Head.

Council should discuss the report with representatives of the Provincial Government to obtain advice and recommendations.

Finally, Council must make a decision on the policy which will be followed in setting up and maintaining the program, and then enact the sewer-use by-law.

When these things have been done, Council should be involved only in periodic reviews of the program or where a change of policy is required. Council should not be involved in the day-to-day workings of the program. If a council member is approached by a local industrialist for an under-the-table resolution of a problem, the council member should simply refer him to the Technical Head. Too often, good control programs have failed because council members have been involved in technical matters.

(c) Role of the Technical Head

The Technical Head of the municipality has a role which places him between Council and the users of the sewer system. To cope with the inevitable pressures placed on him, he must be absolutely sure of the correct course of action to take in any situation. This is best done by having an intimate knowledge of conditions at any given time. Should he not have the experience necessary to make a decision, he should seek advice from others.

In preparing a brief to Council prior to start-up of the control program, the Technical Head must detail the existing conditions and clearly state the capability of the municipality to deal with problems. He must stress the benefits to the municipality of having an active control program and should show, if possible, cost savings in sewer replacement, in treatment plant maintenance and available increased capacity at the treatment plant. The following is a list of data that the Technical Head should be able to present to Council:

- names and addresses of all industries in the municipality;
- types of industries;
- types of industries with liquid wastes;
- those on sanitary sewers;
- those on storm sewers;
- those that information is available on;
- problems that he is aware of;
- staff now working in pollution control;
- capability within his own staff to carry out enforcement work;
- equipment that is available (samplers, flow measurement equipment, etc.)
- sewer diagrams and location of industrial discharges (if available);
- availability of laboratory facilities;
- costs of using a commercial laboratory.

From these data, the Technical Head decides what is needed to establish a control program. Most important is competent staff. The Ministry recommends that one full-time person should be hired when a municipality reaches 20 - 25,000 population, provided there is an average density of industry in the municipality. Before growing to this size, the municipality should have a qualified person working on a part-time basis. This person could also assist in other municipal work, such as the operation of the sewage treatment plant. He should, however, be qualified and trained for the role of enforcer even if he is only working at it on a part-time basis. In municipalities of over 25,000 persons, it is probable that one enforcer should be added for every 50,000 population. Many factors such as concentration of industry in the municipality, complexity of industrial operations, assistance from other municipal departments, amount of lab work involved, availability of mechanical equipment (samplers, etc.),would affect this guideline, but the minimum required coverage should be possible with this arrangement. Based on the above guidelines, the Technical Head should be able to decide how many people he requires.

The brief to Council should include an assessment of the type of staff needed. Can someone on staff who is capable be transferred to the new position, or must someone be hired? In order to determine the requirements in this area, the Technical Head must decide on the qualifications needed by the staff of the enforcement group. The Industrail Wastes Branch of the Ministry suggests that the following qualities be considered for the staff of the enforcement group: (1) character; (2) academic experience; and (3) work experience.

The enforcement officer should be:

(1) A sincere, mature individual with good common sense and capable of rational, unemotional action.

(2) In possession of the Ministry's certificate of qualification as an Industrial Wastes Control Officer, or should be a person with good technical training, preferably with some knowledge of chemistry.

(3) Experienced enough in industrial processes to enable him either to choose an independent laboratory

and know which analyses to request, or to set up a municipal laboratory and conduct routine tests (BOD, COD, solids, pH), whichever is the wish of the municipality.

Should there be only one person on staff, he should have the above qualities. When more people are added to the staff, however, persons strong in specific areas, such as laboratory analyses, industrial processes, may be considered.

The Technical Head should recommend to Council the minimum budget for staff, equipment and outside laboratory services required initially, since the needs of the program may change as it develops. Initially, it is advisable to have any samples resulting from the enforcement program submitted to an outside laboratory for analysis rather than to set up an individual lab, as it is most difficult to predict the needs of the municipality in this area.

After the submission of this brief to the municipal council and the establishment of policy by Council, the Technical Head should have the authorization to acquire whatever staff, equipment and services he needs to implement the control program. As important as hiring staff and obtaining the necessary equipment, is the drafting of job descriptions and the training of the staff. The Technical Head should provide general guidelines for the enforcement group and refer them to literature (and courses such as this) for specific facets of the program. The group should provide the Technical Head with periodic status reports (preferably monthly), and keep him fully informed on those industries not complying with the terms of the sewer-use by-law. The latter point is extremely important because it allows him to decide on a course of action with the problem industries and also to alert the Council and/or the Provincial Government if it appears that an industry is going to appeal for special consideration through non-routine channels. The Technical Head should not become too intimately involved, however, allowing the group to carry out all aspects of the routine enforcement program and, thus, attain a necessary amount of job satisfaction.

(d) Role of the Enforcement Group

The Enforcement Group should proceed by conducting surveys at each industry in the municipality. As a starting point, prepare a list of all the industries, along with water consumption figures, types of processing, points of waste discharge and any other related information which is available. This information should be reviewed with anyone previously involved, such as representatives of the Industrial Wastes Branch of the Ministry of the Environment, to determine the priorities in setting up the program. Once these have been established, a survey or two should be carried out with the assistance of someone with related experience. The Ministry will usually be willing to provide assistance and in this way the members of the Enforcement Group will become experienced in carrying out a survey and be able to obtain the necessary information to prepare a report on each industry. It is only with this initial detailed information on each industry that an inventory can be built up to allow institution of an effective program.

From the results of the initial survey at each industry, those in violation of the terms of the by-law can be discovered. The data for violators should be passed on to the Technical Head with any pertinent comments and recommendations. Action of the industry in one of these ways may then be required:

(1) Pretreatment of wastes to comply with by-law limits;
(2) Payment of the proper sewer service charges according to the by-law; or
(3) If the wastes cannot be accommodated at the sewage treatment plant and a refusal to pretreat further is encountered, the industry should be asked to cut back or cease operations. Punitive measures may be taken according to the terms of the by-law, but these measures are not a solution in themselves and are useful only as an incentive to industry to cooperate.

Hopefully, industry will cooperate, but the municipality must be prepared to take a firm stand if required. If the industry is in compliance with the terms of the sewer-use by-law, a routine monitoring program may be set up. This would consist of checks approximately twice yearly for those well within the limits (to determine if production and/or methods of processing and disposal of wastes have changed), but for those industries approaching the limits of the by-law, more regular surveillance according to the terms of the contract must be carried out. In the cases where an industry is violating the terms of the by-law, constant attention must be maintained. This may involve sampling monthly, weekly or even daily, depending upon the need for detailed information by those negotiating with the industry.

A good location for the Enforcement Group is at the sewage treatment plant. Here, upset conditions can be noted first-hand and there is no substitute for this in the detection and pin-pointing of a problem. For example, a person becomes familiar with the types of problems to be anticipated at the sewage treatment plant; by actually observing the effect on the operation of the plant, he is in the best position to determine the source of the problem. If he is located elsewhere and must drive to the sewage treatment plant to observe the problem, he is at a disadvantage in terms of correcting the problem effectively and quickly. Also, during inactive periods, he may assist the treatment plant staff but at no time should his primary function of Industrial Wastes Control Officer be forgotten. Too often, the Control Officer becomes so involved in the operation of the sewage plant that the duties of enforcing the by-law are neglected.

The Enforcement Group must be kept informed on new industry wishing to locate in the municipality. Prior to the issuing of a building permit, a detailed application form should be submitted by the company for the approval of the Industrial Wastes Control Officer and his supervisors. If there is any question regarding the acceptability of the wastes from the industry, the Industrial Wastes Branch of the Ministry should be asked for comments. It is imperative that written facts be obtained from each industry on the pertinent aspects of their operation (waste flow and characteristics), so that if the company alters production or processing methods and causes problems at the sewage treatment plant, it may be held responsible by the Enforcement Group on the basis of the change in written conditions. Otherwise, it is very difficult to hold any industry responsible for operating changes.

IV. Summary

A good industrial wastes control program consists of:

(a) An informed Council determined to support the control program;
(b) A good sewer-use by-law;

(c) *A planned course of action to ensure success of the program;*
(d) *A competent Technical Head to supervise the program;*
(e) *A competent Enforcement Group of qualified industrial wastes control officers to carry out the field work.*

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